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Potential of the enological use of several Brazilian wood species on the phenolic composition and sensory quality of different wines

António M. Jordão[1,2,*], Ana C. Correia[1], Renato V. Botelho[3], Miriam Ortega-Heras[4], and Maria L. González-SanJosé[4]

[1]Instituto Politécnico de Viseu, Escola Superior Agrária, Viseu, Portugal
[2]Centro de Química de Vila Real (CQ-VR), Portugal
[3]Universidade Estadual do Centro-Oeste (UniCentro), Departamento de Agronomia, Guarapuava, Paraná, Brasil
[4]Departamento de Biotecnología y Ciencia de los Alimentos, Universidad de Burgos, Burgos, España

Abstract. The use of wood species from Brazilian forests has not been the subject of studies on oenology. Thus, the main goal of this study was to carry out a comparative analysis of the impact of several different Brazilian wood species (*Jequitibá*, *Jaqueira*, *Ipê*, *Amburana*, and *Grápia*) on global phenolic parameters, chromatic characteristics, and sensory profile of one red and white wines during a short wood contact time. In addition, toasted European oak wood (*Q. petraea*) was also used. Regarding the specific impact of the use of the different wood species studied, red wines stored in contact during 15 and 30 storage days with *Amburana*, *Grápia*, and *Ipê* wood cubes showed the highest total phenolic content, while for white wines, the highest total phenolic values were detected for the wines stored in contact with *Jequitibá*, *Jaquera*, and *Amburana* wood cubes after 15 storage days. Regarding the sensorial quality, after 30 storage days, red wines stored in contact with *Amburana* and *Jaquera* woods obtained the highest global appreciation scores. For white wines, the highest global appreciation scores were obtained for the wines stored in contact with *Ipê* and *Amburana* wood cubes for 15 days.

1 Introduction

According to OIV and European Union rules, the pieces of wood used for wine production must exclusively come from the *Quercus* genus. However, the high demand for oak wood products may have an ecologically negative impact on harvesting oak trees in forests, where the replacement of trees is not guaranteed. In addition, the increasing demand for oak wood caused a remarkable potential increase in costs due to the limited availability of material, especially for cooperages [1]. Thus, in last years, the possibility of using other wood species, (although not authorized by the European Union and OIV), has also been the object of comparative studies, in red [2] and white wines [3,4].

Brazil is characterized by its great diversity of wood species, some of them traditionally used in alcoholic beverages aging, especially for distillates. However, the use of wood species from Brazilian forests has not been the subject of studies on oenology yet. Thus, considering a great lack of knowledge about the use of woods of Brazilian origin, this work appears as an opportunity to assess the impact of several of these wood species on the red and white wine quality during a short wood contact time. This could be interesting to take potential advantage of the specific and natural characteristics of these wood species and their potential impact on wine characteristics.

Thus, the main goal of this study was to carry out a comparative analysis of the impact of 5 different Brazilian wood species used in the form of toasted cubes on phenolic composition, color properties and sensory profile of red and white wines during a short contact time.

2 Material and methods

2.1 Wood species and experimental work

Five different Brazilian wood species were used: Jequitibá (*Cariniana micranta*), Jaqueira (*Artocarpus heterophyllus*), Ipê (*Handroanthus* sp.), Amburana (*Amburana acreana*), and Grápia (*Apuleia leiocarpa*). In addition, European oak wood (*Q. petraea*) was also used. All the wood sample species were used in the form of cubes with medium toasting level (Fig. 1). The dimensions

*Corresponding author: antoniojordao@esav.ipv.pt

of the wood cubes used were: 1.5x1.0x1.2 cm (length x height x width).

The red (*Touriga Nacional* cv.; alcohol degree 13.8% v/v; pH = 3.50; total acidity of 4.82 g/L tartaric acid; volatile acidity 0.54 g/L acetic acid; free SO_2 26 mg/L) and white (*Encruzado* cv.; alcohol degree 12.7% v/v; pH = 3.30; total acidity of 6.63 g/L tartaric acid; volatile acidity 0.45 g/L acetic acid; free SO_2 30 mg/L) wine samples were stored in contact with the different wood cube species (10 liters each, in duplicate) in glass bottles for 15 and 30 days (only for red wines) at cellar temperature (14-15°C) and stirred manually once a week for 1 min. The concentration of the wood cubes used in this experimental work was 2 g/L. Control red and white wines, without wood contact, were also considered.

Figure 1. Different toasted Brazilian wood cube species used during a short wine contact time.

2.2 Analytical methodologies

Total polyphenolic content was determined according to Ribéreau-Gayon et al. [5] methodology, while non-flavonoid and flavonoid phenols were determined using a method previously described by Kramling and Singleton [6]. Total anthocyanins, total pigments, and polymeric pigments were quantified according to Somers and Evans method [7]. Chromatic characteristics (scanned from a range of 380-770 nm) using the CIELab method, were also determined by the calculation of several chromatic parameters [8]: L^* (%) (lightness), a^* (redness), b^* (yellowness) and chroma (C*). To distinguish the color more accurately, the color difference was also calculated using the following formula: $\Delta E = ((\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2)^{1/2}$. For these coordinates measurements, a DNA phone - Smart analysis system version 4.1 (Parma, Italy) was used.

2.3 Sensory evaluation

After 15 and 30 storage days in contact with the different toasted wood cube species, wines were tasted by 11 expert judges (seven men and four women aged between 35 and 55 years old and with at least 10 years of wine-tasting experience). Measures of 25 mL from each wine sample were presented to the panel at 16-18 °C, in tasting glasses marked with three-digit numbers and in a randomized order. Thus, sensory tributes have been grouped into 4 different attributes: appearance, aroma, taste sensations, and "overall appreciation". The experts scored each sensory attribute (appearance, aroma and taste sensations), on a 1 to 5 points scale (1 = absence; 2 = little intensity; 3 = moderate intensity; 4 = intense; 5 = high intensity), while overall appreciation was scored on a 0 to 20 point scale (0 to 4 = bad; 5 to 9 = mediocre; 10 to 13 = pleasant; 14 to 17 = good; 18 to 20 = very good).

2.4 Statistical analysis

Chemical parameters were measured by triplicate in each duplicate samples of each treatment (wood species and time). Data were expressed as means ± standard deviation of independent experiments (n=2). Statistically significant differences among wines were analysed through a t-student test ($p < 0.05$) and one-way analysis of variance (ANOVA) was used using Fisher's least significant difference (LSD) test to determine significant differences ($p < 0.05$). The statistical analysis was performed using SPSS software version 28.0 (SPSS Inc., Chicago, USA).

3 Results and Discussion

3.1 Global phenolic parameters

The results obtained for total phenols of red and white wines stored during a short time in contact with the different wood cube species are shown in Fig. 2.

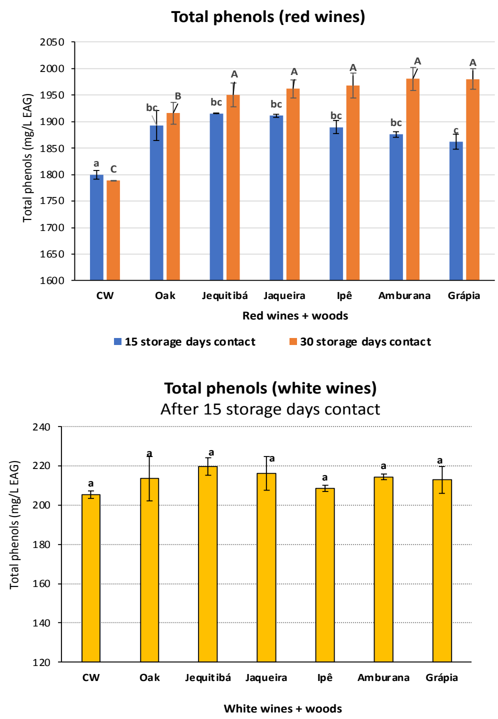

Figure 2. Total phenols quantified in red and white wines stored in contact with different toasted Brazilian wood cube species after 15 (only for white wines) and 30 days.

Data points showing the same letter are not significantly different ($p < 0.05$). Small letters: after 15 storage days of contact; Capital letters: after 30 storage days of contact. CW - control wine (without wood contact).

After the storage time considered, all wines stored in contact with the different toasted wood cube species

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showed higher values for total phenols compared to the control wines (without wood cubes contact). However, this increase was only significantly higher for red wines, while for white wines only a slight increase (without statistical differences) after 15 storage days was observed. This increase is an evident consequence of phenolic molecules transfer from wood to wine. Previous works also reported a similar tendency, where even a short time in contact with wood is sufficient for a significant increase of wood phenols in wines, particularly when wood pieces (chips or cubes) are used [3,9]. Among the red wines stored in contact with the different wood cube species, wines stored in contact with toasted cubes from *Ipê*, *Amburana* and *Grápia* species showed a tendency for the highest total phenol values (values between 1967 and 1980 mg/L gallic acid equivalents) after 30 days of wood contact. On the other hand, red wine stored in contact with toasted oak cubes showed values between 1892 and 1915 mg/L gallic acid equivalents after 15 and 30 days of wood contact, respectively. For white wines stored in contact with the different wood cube species, wine samples stored in contact with toasted cubes from *Jequitibá*, *Amburana* and *Grápia* species, showed a tendency for higher values of total phenols values (values between 214 and 219 mg/L gallic acid equivalents) after 15 days of wood contact.

Regarding non-flavonoid phenols (Fig. 3), in general, all red wines showed similar values after 15 and 30 storage days, except for red wine stored in contact with *Grápia* wood cubes for 15 days, which showed significantly higher values compared to the remaining wines. For white wines, no significant differences were detected between all the wines after 15 days of wood contact with the different wood species. For flavonoid phenols, in general, all red wines stored in contact with the different wood cube species showed a tendency for higher values compared to control wine (Fig. 3). During the first 15 days of wood contact, this tendency was more evident for red wines stored in contact with *oak*, *Jequitibá* and *Jaqueira* wood cube species (values between 1800 and 1819 mg/L gallic acid equivalents). However, after 30 days of wood contact, the wines stored in contact with cubes from *Amburana*, *Ipê* and *Grápia* species showed significantly higher values (values between 1812 and 1824 mg/L gallic acid equivalents). This tendency may correspond to a higher potential of several condensed tannins and (+)-catechin in these wood species. Previous studies, describe an abundance of condensed tannins and (+)-catechin in different wood species with potential use in oenology such as cherry and walnut [10,11]. Thus, future studies of phenolic characterization of these wood species must be carried out, to prove their potential in flavonoid phenols. Finally, for white wines, after 15 days stored in contact with the different wood cube species, all wines (including control wine) showed similar values for flavonoid phenols. However, it should be noted that the control wine (stored without wood contact) showed a tendency for slightly lower flavonoid values compared to remaining white wines stored in contact with the different wood cube species.

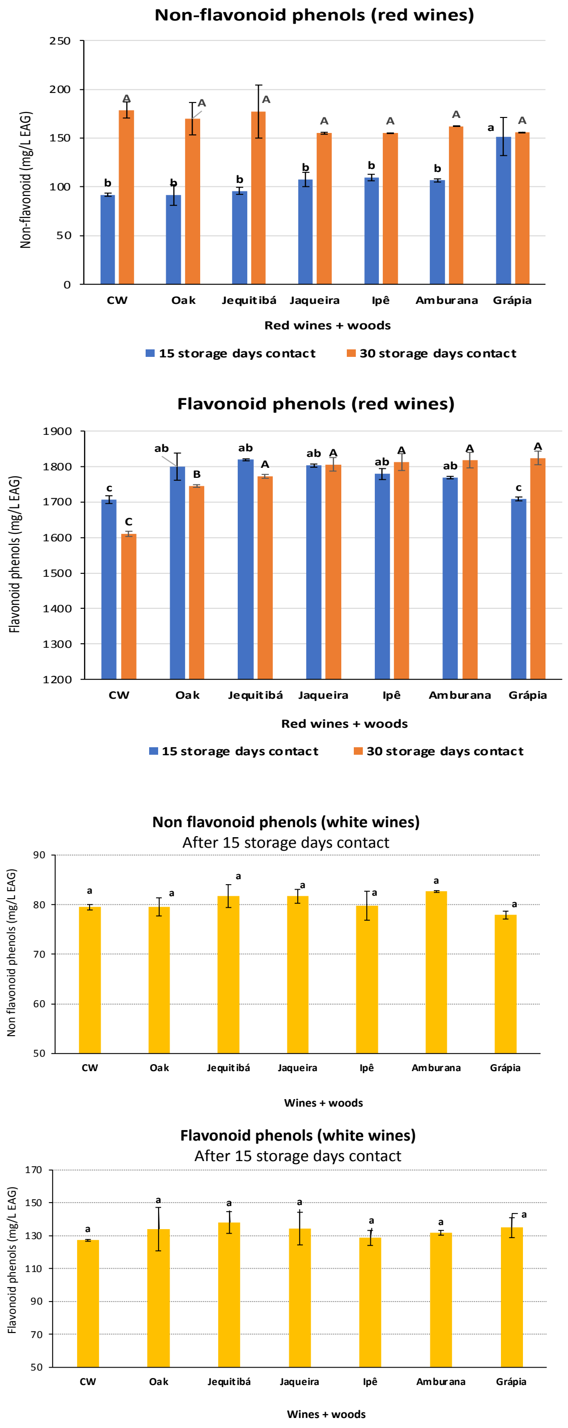


Figure 3. Flavonoid and non-flavonoid phenols quantified in red and white wines stored in contact with different toasted Brazilian wood cube species after 15 (only for white wines) and 30 days.

Data points showing the same letter are not significantly different ($p < 0.05$). Small letters: after 15 storage days of contact; Capital letters: after 30 storage days of contact. CW - control wine (without wood contact).

The results obtained for total anthocyanins of red wines after 15 and 30 storage days in contact with the different wood cube species are shown in Fig. 4. After 15 and 30 storage days, the control wine (without wood contact) showed a tendency for slightly higher total anthocyanin content compared to the remaining wines stored in contact with the different wood cube species. Several works reported the important role of hydrolysable tannins extracted from wood, particularly from oak in anthocyanin stabilization and color protection, because ellagitannins are involved in stabilizing anthocyanin structures and demonstrate important antioxidant properties [12]. However, other studies reported a continuous decrease in the anthocyanin contents for red wines aged in contact with wood, because of oxidation reactions during aging and from condensation reactions between anthocyanins and certain wood molecules. In that case, these reactions generate large, insoluble, and precipitable polymers, and new pigments that are not quantified in total anthocyanin estimation [13,14]. In our work, the slight difference between the wines in terms of total anthocyanin content, namely between the control wine and the wines stored in contact with the different wood cube species, could be related to the short period of contact time between the wines and the wood or even with a low concentration of wood cubes used. However, further studies will be necessary.

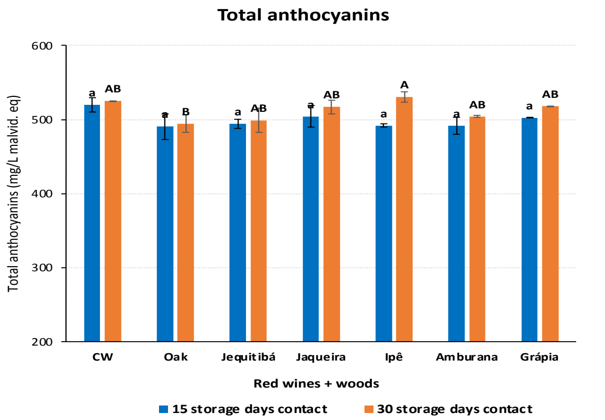


Figure 4. Total anthocyanins quantified in red wines stored in contact with different toasted Brazilian wood cube species after 15 and 30 days.

Data points showing the same letter are not significantly different ($p < 0.05$). Small letters: after 15 storage days of contact; Capital letters: after 30 storage days of contact. CW - control wine (without wood contact).

The results of total and polymeric pigments for the red wines during storage in contact with the different wood cube species are shown in Fig. 5. In general, for total pigments similar values were found between all red wines (including for control wine) after 15 and 30 storage days. The only exception was the wine stored in contact with *Jaqueira* wood cubes after 15 days of contact, which showed a significantly higher value compared to the remaining red wines.

Considering the results obtained for polymeric pigments during 30 storage days, a clear increase in the values for all red wines stored in contact with the different wood cube species was detected. After 30 storage days, the red wines stored in contact with oak cubes showed a significantly highest value (1.90 abs. un.). The remaining red wines stored in contact with the different wood species showed similar values (ranging between 1.77 and 1.80). The increase of polymeric pigments during red wine storage in contact with wood cubes is a consequence of different reactions involving ellagitannins from woods and wine anthocyanins forming several molecular linkages [15]. These formed compounds, called polymeric pigments contribute to color stability in red wines over time [16]. In this case, there seems to have been a greater reactivity between the red wine compounds and wood cube components independently of the wood species used.

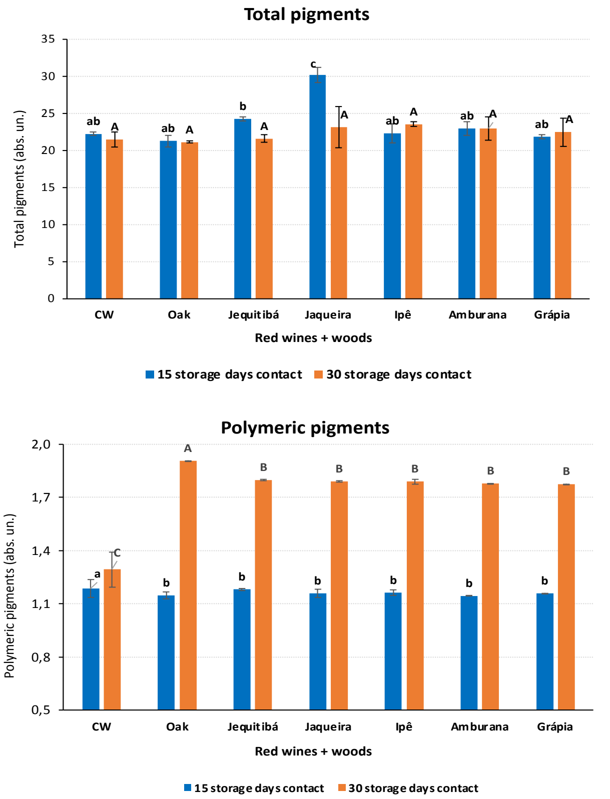


Figure 5. Total and polymeric pigments quantified in red wines stored in contact with different toasted Brazilian wood cube species after 15 and 30 days.

Data points showing the same letter are not significantly different ($p < 0.05$). Small letters: after 15 storage days of contact; Capital letters: after 30 storage days of contact. CW - control wine (without wood contact).

3.2 Chromatic characteristics

The evolution of chromatic characteristics of red and white wines stored in contact with different wood cube species are shown in Tables 1 and 2. For red wines, the most important chromatic changes were detected after 30 storage days. Thus, in general, an evident $a*$ values (redness) decrease was detected for all red wines stored in contact with the different wood cube species (Table 1). After 30 storage days, the control wine showed one of the significantly highest $a*$ values (35.11 expressed by the CIELab coordinates). This decrease confirms the slight total anthocyanin content reduction for most of the red wines stored in contact with wood cubes already reported in Fig. 4. Furthermore, in general, the addition of wood cubes induced a reduction of the $L*$ values (lightness) compared to control wine (except for wine stored in contact with *Grápia* wood cubes, which showed similar values compared to control wine). Concerning *b** values (yellowness) and after 30 storage days, control wine and wine stored in contact with *Grápia* wood cubes showed similar values, while the remaining wines showed a significantly lower value (Table 1). As a result of the differences found for the different color coordinates, the values obtained for color difference (ΔE^*) between control wine and wines stored in contact with different wood cube species for 30 days showed that only red wines stored with *Jequitibá*, oak and *Jaqueira* wood cubes showed values higher than two CIELab units (9.58, 8.24 and 2.95, respectively). Martínez et al. [17] indicated that ΔE^* values up to 2.7 CIELAB units represent chromatic changes in red wines that can be perceived by the human eye.

Table 1. Chromatic characteristics using the CIELab method coordinates quantified in red wines stored in contact with different toasted Brazilian wood cube species after 15 and 30 days.

	CIELab coordinates			
Red wines+ woods	***L****	***a****	***b****	**ΔE***
	15 storage days of contact			
CW	6.17±0.78^{a,b}	33.07±2.06^{a,b}	10.58±1.35^{a,b}	--
Oak	5.60±0.14^{b}	31.85±0.38^{a,b}	9.61±0.20^{b}	0.62±0.40^{c}
Jequitibá	5.60±0.28^{a,b}	31.82±0.84^{a,b}	9.60±0.48^{a,b}	1.14±0.25^{c}
Jaqueira	5.00±0.01^{b}	29.95±0.04^{b}	8.61±0.02^{b}	6.50±0.04^{a}
Ipê	5.00±0.28^{a}	32.98±0.76^{a}	10.19±0.46^{a}	3.01±0.92^{b}
Amburana	6.00±0.14^{a}	33.17±0.35^{a}	10.30±0.23^{a}	2.77±0.44^{b}
Grápia	5.95±0.07^{a}	32.93±0.16^{a}	10.19±0.09^{a}	3.02±0.19^{b}
	30 storage days of contact			
CW	7.00±0.14^{a}	35.11±0.32^{a}	12.05±0.29^{a}	--
Oak	4.55±0.07^{b,c}	28.09±0.39^{b}	7.81±0.14^{b}	8.24±0.42^{b}
Jequitibá	3.90±0.14^{d}	25.25±0.71^{c}	6.77±23^{c}	9.58±0.74^{a}
Jaqueira	5.20±0.14^{e}	30.30±0.52^{d}	8.87±0.27^{d}	2.95±0.60^{c}
Ipê	6.75±0.07^{a}	34.50±0.07^{a,b}	11.54±0.09^{a}	1.44±0.13^{d}
Amburana	6.15±0.07^{b}	33.20±0.27^{b,e}	10.59±0.17^{e}	1.04±0.33^{d}
Grápia	7.10±0.28^{a}	35.11±0.46^{a}	12.15±0.47^{a}	0.92±0.60^{d}

*L** (%; lightness); *a** (from green to red); *b** (from blue to yellow); ΔE^* total color difference; the values corresponding to ΔE^* were obtained taking as a reference control red wine without contact (CW); * Values with same letters for each CIELab coordinate (in column) and storage time are not significantly different ($p < 0.05$); average values of three replicates.

Finally, for white wines stored in contact with the different wood cube species, in general, a significant increase of *b** values (yellowness) compared to control wine were detected after 15 storage days (Table 2). This increase was particularly evident for wines stored in contact with *Ipê* and *Amburana* wood cubes. On the other hand, as expected for white wines, the *a** values were all extremely low (all negative values) reflecting the obvious non-existence of red color in white wines and a tendency for a slightly blue color, especially for the white wines stored in contact also with *Ipê* and *Amburana* wood cubes, where the values were significantly different. The results obtained for color difference (ΔE^*) between control wine and wines stored in contact with different wood cube species showed that all values were lower than two CIELab units, indicating that the color difference could not be detected by human eyes [18]. Probably, a more extended storage time in contact with the different wood cube species could induce clearer evidence of color changes in white wines.

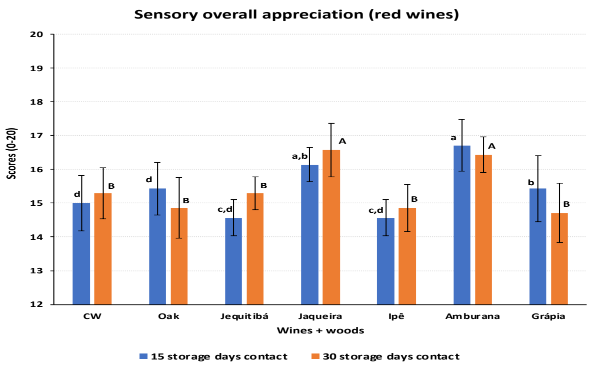
Table 2. Chromatic characteristics using CIELab method coordinates quantified in white wines stored in contact with different toasted Brazilian wood cube species after 15 days.

	CIELab coordinates			
White wines + woods	***L****	***a****	***b****	**ΔE***
	15 storage days of contact			
CW	97.30±0.14^{a}	-0.60±0.00^{c}	4.68±0.01^{e}	--
Oak	96.80±0.00^{a}	-0.67±0.01^{c}	4.99±0.00^{c}	0.51±0.00^{b,c}
Jequitibá	96.70±0.14^{a}	-0.64±0.01^{c}	4.79±0.08^{d,e}	0.48±0.12^{b,c}
Jaqueira	97.05±0.21^{a}	-0.59±.00^{b}	4.98±0.04^{c,d}	0.63±0.05^{c,d}
Ipê	97.75±0.21^{a}	-0.79±0.00^{a}	5.27±0.02^{b}	0.88±0.15^{a,b}
Amburana	96.70±0.14^{a}	-0.79±0.00^{a}	5.52±0.03^{a}	0.76±0.04^{a}
Grápia	96.80±0.14^{a}	-0.56±0.00^{b}	4.86±0.03^{c,d,e}	0.34±0.14^{b,c,d}

*L** (%; lightness); *a** (from green to red); *b** (from blue to yellow); ΔE^* total color difference; the values corresponding to ΔE^* were obtained taking as a reference control white wine without contact (CW); * Values with same letters for each CIELab coordinate (in column) and storage time are not significantly different ($p <$ 0.05); average values of three replicates.

3.3 Sensory evaluation

The results for overall appreciation scores obtained from sensory analysis of red and white wines stored in contact with the different wood cube species are shown in Fig. 6.



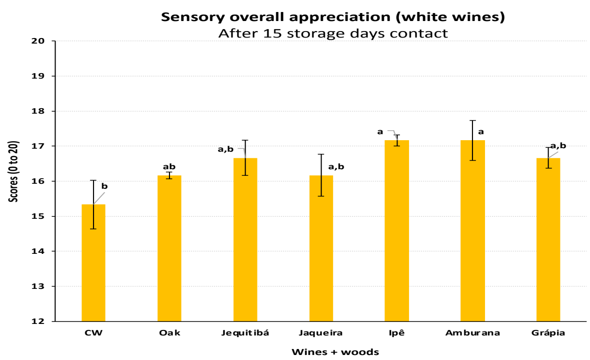


Figure 6. Sensory overall appreciation scores of the wines stored in contact with different toasted Brazilian wood cube species after 15 (only for white wines) and 30 days.

Data points showing the same letter are not significantly different ($p < 0.05$). Small letters: after 15 storage days of contact; Capital letters: after 30 storage days of contact. CW - control wine (without wood contact).

The results pointed out in evidence significant differences between red wines stored in contact with *Amburana* and *Jaqueira* wood cube species in relation to the other red wines. These two wines showed the best overall appreciation scores from the panel test. This tendency was observed for the two storage times considered (15 and 30 days). The remaining wines had similar scores. In addition, wines stored during 15 and 30 days in contact with *Amburana* and *Jaqueira* wood cube species also showed the best scores for the sensory attributes related to aroma and taste (data not shown).

Finally, for white wines, the results for overall appreciation scores highlighted those wines stored in contact *Ipê* and *Amburana* wood cubes showed the significantly highest scores. In addition, it was clear that the wine wood contact for 15 days induced an increase in overall appreciation scores for all wines compared to the control wine. In addition, after 15 days of wood contact, white wine stored with *Amburana* wood showed the best scores for sensory attributes related to aroma, namely almond, spice and aroma intensity. On the other hand, white wine stored in contact with *Ipê* wood cubes showed the best scores for several taste attributes, namely body and astringency (data not shown).

4 Conclusions

This study provides relevant information on the potential use of different Brazilian wood species in oenology. In addition, under the experimental conditions of this research, the results point out that several specific wood species, namely *Amburana* wood has been one of the species with the highest potential oenological interest, even in comparison with the results obtained for oak wood. However, further research, including more detailed wine chemical analyses, will be necessary to improve the knowledge about the potential impact of the use of these wood species on wine quality. In addition, the use of a more extended storage time, different wood cube concentrations and toasting levels will also be other points to be considered in future studies.

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