IVES Technical Reviews vine & wine

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Wine aging: a question of closure?

Sourced from the research article "Wine aging: a bottleneck story" (Nature Science of Food, 2019)[1].

>>> From a case study of bottles of white wine aged in the cellar, a multidisciplinary approach integrating sensory, oenological and metabolomic analyses of wine as well as a study of oxygen transfers highlighted the importance of the glass-stopper interface[1]. The transfer of oxygen at this interface can make a significant contribution to oxidation during the aging of wine in bottle. <<<

■ Background

Aging mechanisms in bottle depend in particular on chemical autoxidation, which is favored by the supply of oxygen to the wine. The stopper therefore represents the last line of defense in limiting reactions involved in oxygen consumption. Many studies have focused on the gas barrier properties of different types of closure, comparing natural corks of various quality levels with agglomerated corks, synthetic corks or screwcaps[2]. While there are obvious differences in oxygen permeability between the major types of closure, these do not explain why uncontrolled oxidation can sometimes occur in a sporadic fashion. In this study, the issue of oxygen consumption by white wines during bottle aging was investigated, to assess the contribution of the interface between the cork stopper and the neck. From sporadic oxidation observed in several bottles of white wine from the same vintage and from the same production batch, a multidisciplinary approach was adopted, combining sensory assessment, targeted and non-targeted chemical analysis, as well as a study of oxygen transfers for the stopper-neck system.

■ Study performed and main results

Four bottles of white Burgundy wine (Chardonnay grape variety, Marsannay appellation) were investigated (Fig. 1), two from the 2005 vintage and two others from the 2006 vintage. The wine for each vintage came from the same 5 hL batch. For each vintage, one bottle was suspected of being non-oxidized and the other oxidized, due to the difference in color visible through the glass of the bottle. To avoid damage to the neck of the bottle surrounding the stopper, the wine contained in the bottles was sampled under an inert atmosphere (argon) by piercing the bottle. One portion of the wine was used for sensory analysis by a trained panel (15 people) and another portion for chemical analysis, analysis of the usual oenological parameters, and metabolomic analysis using ultra-high resolution mass spectrometry[3]. For both vintages, the wines suspected of being oxidized (Ox) were significantly higher in oxidative notes (in both orthonasal and retronasal perception) (Fig. 1, tested by ANOVA) than the wines assumed to be non-oxidized (NoOx).

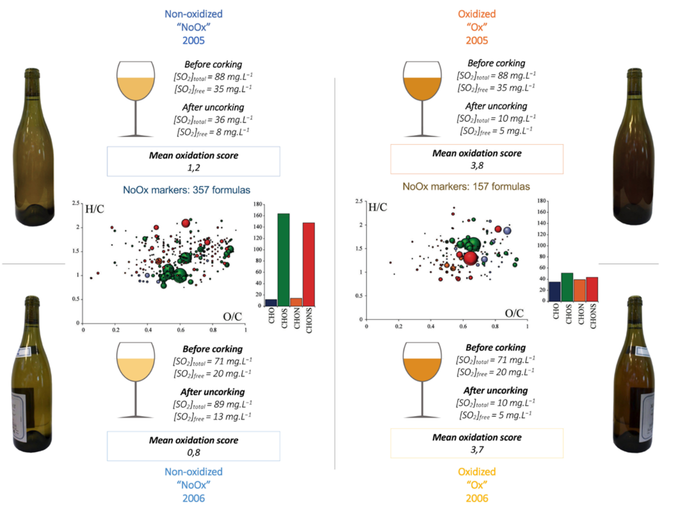

Figure 1. Wine colors (shown in the glasses, from CIELab measurements), oxidation scores (-5 = strong reduction, +5 = strong oxidation), SO_2* content, and metabolomic analyses (van Krevelen diagrams and count of empirical formulas that differentiate oxidized "Ox" and non-oxidized "NoOx" wines). (* Note: the initial SO_2 content was measured by a different laboratory, for quality control purposes at the time of bottling).

A moderate supply of oxygen leads to multiple chemical reactions involving SO_2, in particular its nucleophilic addition to quinones, with preferential consumption of free SO_2. In contrast, a plentiful supply of oxygen can involve both free SO_2 and combined SO_2. Thus, the observed decrease in the total SO_2 concentration (free plus combined) in the oxidized wines, of both vintages, clearly illustrates the higher level of oxygenation sustained during bottle aging (Fig. 1), in line with the sensory results. As shown by the colors of the wines (Fig. 1), the Ox wines were significantly more oxidized than the NoOx wines, with a color difference detectable by the naked eye ($\Delta E > 25$), a consequence of the formation of brown oxidation pigments.

Non-targeted metabolomic analysis using ultra-high resolution mass spectrometry showed that the several thousand marker compounds for non-oxidized wines are mainly nitrogen- and sulfur-containing compounds CHOS and CHONS[4] (sulfonated polyphenols, amino acids/peptides, etc.) while these had been consumed through molecular mechanisms following a high level of oxygenation in the oxidized bottles (Fig. 1).

From the oxygen diffusion coefficients determined experimentally using a manometric method developed in the laboratory[5], first through the system consisting of the cork stopper inserted into the neck, then, after cork removal, through the cork alone without the glass-stopper interface, different oxygen transmission rates (OTRs) could be determined (Fig. 2).

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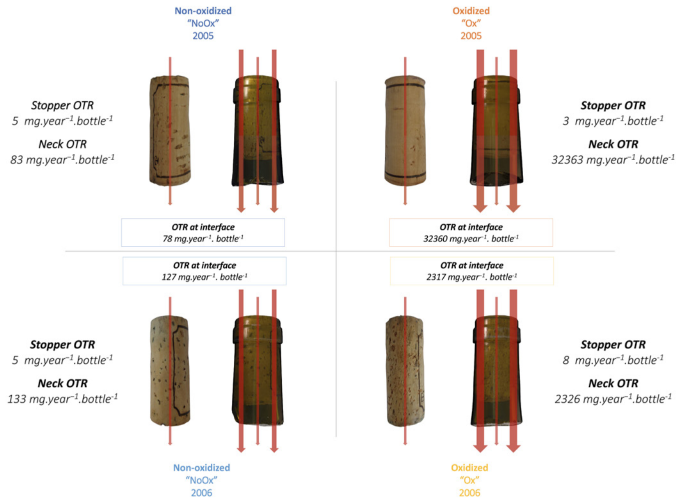

Figure 2. Oxygen transmission rate (OTR) measured through the cork stopper alone (cork), the stopper + neck assembly (neck) and the interface.

The values obtained for the stopper + neck system are markedly higher for the oxidized wines than for the non-oxidized wines. Oxygen transmission, measured for the cork stopper once extracted from the neck, is about the same for all four stoppers, with a value similar to those measured in cork in previous work[6]. These results therefore highlight the important role played by the interface between the cork stopper and the glass neck[7].

These values, which seem very high, were calculated from measurements carried out under conditions different from those applied during storage of the wine (dry sample, without partial pressure of water vapor and ethanol). It is also important to note that these values correspond to the barrier properties of the stopper in its final state, after several years of storage, and that the barrier properties may have changed over time. Nevertheless, the data obtained clearly shows that oxygen transmission at the stopper-neck interface is always higher than transmission through the cork stopper alone. In this case, therefore, the oxidation of the wine is not due to the poor barrier properties of the cork, but to an uncontrolled transfer of oxygen at the interface, as had already been predicted from a study carried out in the laboratory on a statistically representative set of natural cork samples, inserted or not into a bottle neck[6].

■ Conclusions and future work

Our results show that the resistance of a wine to oxidation during bottle aging can be modulated by a plentiful supply of oxygen at the interface between the cork stopper and the glass neck, independently of the intrinsic barrier properties of the closure (the four corks exhibiting similar values in this case study). From a practical point of view, these results encourage us to look further into the role of the surface treatment of closures, as well as the effect of their density and their mechanical properties, but also the quality of bottling (the closure insertion process). In addition, the role of the glass neck (its dimensions or indeed surface properties) remains to be explored. Thus, taking into consideration the fact that several other factors can contribute to the oxidative stability of a wine (matrix effect linked to the vine metabolism in connection with the environmental conditions in the vineyard, to changes in winemaking practices such as reduced SO_2 additions, etc.), a multidisciplinary investigation of this type should be extended to a greater number of samples, to allow ranking of the contributory factors. ■

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