**OTR and red wine aroma**

The influence of oxygen on the sensory characteristics of red wine has been long known, since Louis Pasteur observed that, by exposing red wine to air, the astringent character of young red wine was softened, and the bouquet improved. Nowadays, it is generally accepted that a moderate exposure to oxygen can be beneficial for the overall sensory quality of the wines. Insufficient oxygen can prevent softening of mouthfeel characters and favors excessive accumulation of reductive aroma compounds such as hydrogen sulfide and mercaptans, which can be highly detrimental to wine aroma quality (See Nomacorc newsletter #3). At the same time, excessive exposure to oxygen can cause oxidative spoilage of the wine, with irreversible loss of fruity and floral varietal aromas. Due to this complex response, proper management of oxygen exposure in the winery remains challenging for the modern wine industry, also in consideration to the intrinsic variability of wine characteristics in relation to origin of grapes, vintage, terroir, and winemaking variables.

In consideration of such variability, the main question that winemakers are facing is how much oxygen a wine needs to achieve optimal expression of its sensory potential without showing reduction or oxidation faults. Between production and consumption, wines spend a considerable portion of their life in bottle, particularly in the case of red wine. Therefore, the selection of appropriate packaging solutions is a crucial aspect of wine quality. In particular, as the different closures available on the market have different oxygen barrier properties (a parameter commonly referred to as OTR), selection of closures with the appropriate OTR become a crucial tool for achieving optimal oxygen exposure.

**Figure 1. Effect of in-bottle oxygen exposure on the aroma profile of Grenache wines, and implications for closure selection based on OTR values and consistency.**

![Diagram showing the effect of in-bottle oxygen exposure on the aroma profile of Grenache wines.](image-url)
Depending on the materials and technology adopted to produce the closure, OTR can vary to a large extent. Screw cap closures generally offer very low OTRs, due to the minimum amount of oxygen permeating through the liner. Saratin liners have been reported to have an OTR of 0.03 ±0.03mg O₂/year (Crochière 2007), while values are slightly higher (but also more inconsistent) in the case of Saranex liners (0.7 ± 0.7mg O₂/year) (Crochière 2007). This range of OTR currently available in screw cap liners is therefore relatively limited. Microagglomerated closures are also reported to have relatively low OTR (Lopes et al. 2007), although permeability can vary depending on the producer, and most producers do not give a specific value or have a range of OTR. Therefore, although there is a general tendency to assume similar performances for all closures in this category, some key characteristics can actually vary significantly among different producers. Likewise, the characteristics of synthetic closures can vary depending on the technology of production. Injection molding offers limited possibilities to adjust OTR, while co-extrusion, allows to obtain a broad range of defined OTR, providing winemakers with OTR values that can fit the specific needs of each wine. For example, Nomacorc co-extruded closures offer an OTR as high as 3.5 mg/year (Smart+), down to 1.1 mg/year for the new Select 300. Conversely, natural cork can have extremely variable OTR, due to the intrinsic structural variability of cork itself (Godden et al. 2001). Measures (Lopes et al. 2005 and 2006) under conditions of humidity simulating those occurring in a wine bottle indicate values between 0.05-3.35 mg of oxygen per year even for a very limited sample size. While this variation appears to be extremely large and possibly linked to specific bottling conditions, most authors have reported large variation in OTR for natural closures (Godden et al. 2005, Limmer 2006). At present, it is not possible to put on the market natural cork closures with defined OTR.

Figure 1 shows an example of the potentialities (and difficulties) of closure selection and OTR management to create wines with different sensory profiles. As it can be observed, by exposing the same wine to increasing amounts of oxygen, it is possible to obtain different aroma profiles after 10 months in the bottle. Low oxygen exposure (0.24 mg O₂ and 0.57 mg O₂ in ten months in 375 mL bottles) resulted in wines exhibiting low intensity of red fruit aromas, and mainly characterized by animal/reduction notes, a feature often observed in Grenache wines matured under reductive conditions. Conversely, increasing oxygen exposure in ten months to 2.4 mg O₂ to 3.57 mg O₂ allowed better expression of red fruit and caramel aromas, decreasing at the same time the incidence of the animal note. This could be attributed to lower concentration of the aroma compounds involved in the animal notes, allowing expression of fruity aromas.

If we compare this data with the values present in the literature and/or provided by different closure manufacturers, we can deduce that closures such as screw caps allow oxygen exposures in a range close to the profiles obtained at 0.24 and 0.57 mg O₂ (blue and red
lines), and therefore are more prone to deliver wines with lower fruit expression and higher animal notes. Although these closures can have more consistent OTR than natural corks, they cover a low range of oxygen exposure, not giving to winemakers the option of choosing the degree of oxygen exposure most appropriate for a specific wine. On the other hand, natural cork closures, due to the intrinsic variability of cork composition, can offer a rather broad range of oxygen exposures (even within the same batch of closures), potentially allowing, over a range of bottles of the same wine, either optimal expression of fruit aromas (green line) or dominance of animal notes (blue and red lines). From this point of view, synthetic co-extruded closures (e.g. Nomacorc) closures offer the advantage of a range of different OTR available, allowing winemakers to choose the degree of oxygen exposure most appropriate for their wines.

In spite of its key role in defining the evolution of wine sensory properties during bottle maturation, the value of OTR declared by the manufacturer is not the only key parameter that defines closure performance. Indeed, in order to deliver wines which will evolve in the bottle as the winemaker intended, the consistency of OTR is essential. In practice, once the winemaker has decided the OTR that is most appropriate for his wine(s), this OTR value will have to be rather consistent within single batches as well as across batches, in order to allow uniform aging. Figure 2 shows the variation in OTR values (expressed as %CV over 5 closures of the same batch) of different inner seal closure types, as obtained from measures with fluorescence method (Dieval et al. 2011). In agreement with Brotto et al. (2010), synthetic closures, in particular extruded products, show very low CV%, reflecting the intrinsic nature of the manufacturing process, which allows a high degree of control of production variables. Higher %CV were observed for natural cork-based products, consistent with the relatively unpredictable characteristics of the raw material. The high variations observed were often due to leakage, which in some cases made the measure impossible (labelled as leakage (L) on all closures).

In conclusion, understanding the influence of OTR on wine sensory quality allows to deliver wines which will reflect, upon consumption, the intention of the winemaker. Availability of a range of OTRs values, as well as consistency of those values across different batches, are key factors to succesful implementation of oxygen management strategies focused on closure selection.

Suggested readings