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Vinification and aging: how much oxygen to add and when?

>>> In his day, Pasteur already identified the importance of oxygen to wine and his famous quotation is often repeated: "It's oxygen that *makes* wine." A great deal of scientific work has been done on the impact of oxygen on wine. This article aims to review current thinking on the quantities of oxygen that are, or should be, supplied to wine during vinification and aging. <<<

Oxygen management only makes sense if its impact on the quality of wine, of which taste and aroma are the two main components, is fully controlled. It is commonly accepted in the literature that there is a cumulative oxygen requirement of between 20 and 50 mg/L for white wine and between 40 and 80 mg/L for red wine, to avoid problems associated with reduction and oxidation[1]. These prescriptions are nevertheless debatable, and need to be put into perspective depending on the specific characteristics of each wine. Still today, tasting remains the only technique that allows an enologist to decide on oxygen additions to wine.

■ During fermentation, avoid deficiency

During the winemaking process, the alcoholic fermentation is the only stage at which large quantities of oxygen should be supplied. Oxygen deficiency is one of the main causes of stuck ferments and the addition of at least 10-15 mg/L oxygen is required. The best time to add oxygen, for both reds and whites, is at the end of the growth phase (after a drop of 10 kg/m^3 in must density) and it is still highly effective at mid fermentation. Additions prior to this are of no interest for the yeasts and may even cause oxidation of the must. Pumping over the full volume of the tank with aeration (facilitating removal of CO_2 and introduction of O_2) supplies between 2 and 6.5 mg/L (saturation of the must with oxygen).

■ Aging, give the wine just the right amount

Oxygen supplied during aging should give structure to the wine, contribute to its aromatic expression and bring it to an optimum physico-chemical state for bottling and subsequent development. The micro-oxygenation technique finds its application during aging in tank, to give the wine just the right amount. The oxygen supplied is consumed by compounds in the wine, leaving no measurable dissolved oxygen.

Of course, the determination of the right dose for the wine is totally empirical, and remains dependent on the know-how and discernment of each enologist, with all the flaws that this approach can involve. In general, the doses introduced are between 1 and 4 mg O_2/L per month between the alcoholic and malolactic fermentations. The saturation level for oxygen in wine is 8.4 mg/L at 20 °C and the consumption kinetics at 15 °C are approximately 10 days for red wine and 30 days for white wine.

These values are particularly dependent on temperature (Figure 1) and also the quantity and composition of the lees. Hence, a wine on lees will consume between 0.5 and 1.5 mg/L per hour while a filtered wine (0.8 µm) will consume between 0.1 and 0.3 mg/L per hour[2].

The duration of micro-oxygenation can vary from a few days to a month, especially when inner staves are used in place of barrel aging. During barrel aging, it is the wood that allows oxygen to be supplied to the wine.

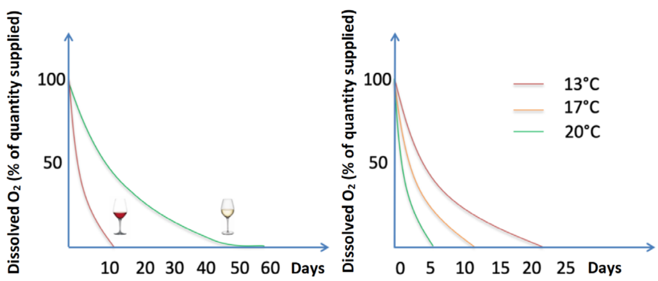

Figure 1. Oxygen consumption kinetics[2].

Owing to its properties, the oak allows oxygen transfer between the staves, in particular, and through the bung, and values vary from 16 to 40 mg/L per year[3].

It should also be noted that 10 mg/L is added during the first month of aging due to desorption of the oxygen contained in the wood (coupled impregnation/release phenomenon)[3].

The humidity and temperature will influence the amounts of oxygen that are supplied to the wine. Permeability values

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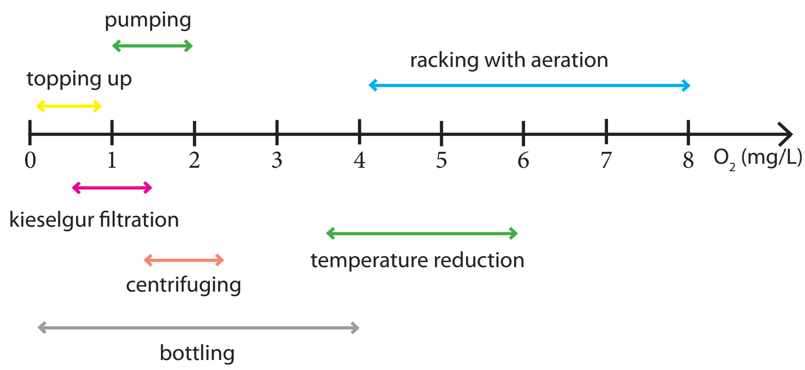

Figure 2. Possible oxygen intake during winemaking operations (Castellari et al., 2004)[5].

for oak can be found in the literature but they are very variable, difficult to exploit and depend on many factors: geographical origin of the wood, grain size, preparation and storage of the wood, stave preparation, number of staves per barrel, barrel toasting, barrel age, time the wine spends in barrel, type of wine in the barrel, etc. The natural oxygen permeability rate through the barrel is between 1.1 and 2 mg/L per month[4] as from the second month over at least a year[6].

To all this must be added the work done during aging, which also adds significant quantities of oxygen: transfer, filtration, racking, bottling, etc. The material balance carried out throughout the winemaking chain, remaining within the range of 20/50 mg/L for whites and 40/80 mg/L for reds, should make it possible to avoid problems associated with oxidation or reduction of the wine (Figure 2). In summary, the oxygen intake during vinification can be illustrated as follows (Figure 3). ■

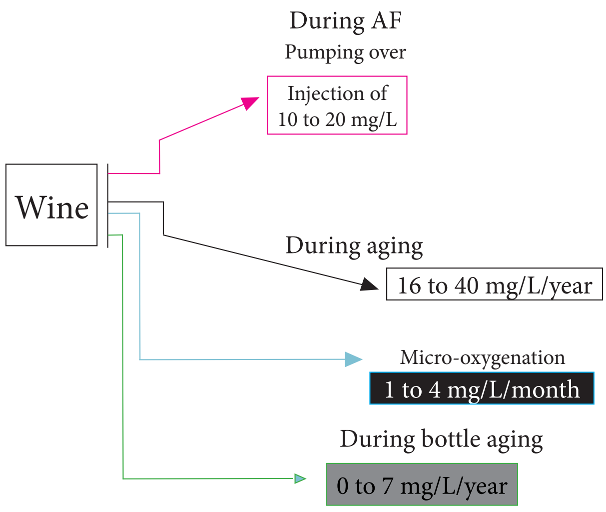

Figure 3. Oxygen intake during vinification and aging[2].

What about the cork?

The second porous material associated with the same issue is the cork. While most authors consider that the compression of the cork by the neck is sufficient to reduce the porosity and transform the cork into a partial barrier to oxygen, uncontrolled oxidation of wine can occur even with very good quality closures.

For optimal aging of wine in bottle, a knowledge of the different types of closure is required. Closure techniques have evolved, both in terms of bottles and corking machines and the appearance of new types of closure on the market (agglomerated corks, synthetic materials, screw caps). Many manufacturers now characterize closures by measurement of the Oxygen Transfer Rate (OTR, in units of $mol.m^{-2}.s^{-1}$).

Given that the cork is compressed in the neck of the bottle, and therefore has a surface area for exchange of $2.69x10^{-4}$ m^2, Crouvisier-Urion et al. (2018)[7] report median permeation rates of 2.05 mgO_2/year for natural corks, 5.15 mgO_2/year for synthetic corks, 0.2 mgO_2/year for micro-agglomerated corks and 0.93 mgO_2/year for screw caps (quantities of oxygen supplied to be read in mgO_2/year/bottle).

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