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Impact of stopper type on oxygen ingress during wine bottling when using an inert gas cover

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• White wines are normally not stored in bottles for a long time due to the progressive oxidation that leads to loss of delicate aromas. In contrast, red wines are normally aged longer in the bottle, given that oxygen uptake has been linked to a number of positive effects, including 1) enhanced and more stable color, 2) less astringency, and 3) improved "bouquet".

• Knowing the oxygen *permeability* of each stopper type is an important predictor of the amount of oxidation the bottled wine will experience "down the road". But according to these authors, the type – *shape*- of stopper can also influence the amount of oxygen that gets into the wine at the time of bottling. The goal of this study was to determine the effect of stopper type on the amount of oxygen that enters the wine during bottling.

• The authors compared **8 types of corks**: 3 natural corks, 2 "technical" stoppers, 2 synthetic stoppers (one extruded, one moulded), and 1 metal screw cap with multilayer liner. Briefly, the technical stoppers had diameters similar to the natural corks, but were much shorter and denser. The synthetic stoppers had significantly lower diameters than the other stoppers, and their density was 2-3 times greater than the natural corks. Something rather unusual about this study is that, instead of bottling wine, the authors bottled a *manganese sulfate solution* that would later facilitate the measurement of the amount of oxygen ingress for each stopper type. (See original text for the simple chemical reaction involved, as well as the specific brands of stoppers tested.)

• Twenty-four hours after the bottling process, 6 bottles corresponding to each type of stopper were analyzed for dissolved oxygen. Besides this *"measured oxygen concentration"*, the authors also calculated a *"theoretical maximal oxygen concentration"*. They did this by measuring the headspace volume (determined by the height of each stopper), and the headspace overpressure (using a pressure gauge), and then applying the "perfect gas law" to elucidate the oxygen concentration. *[The perfect gas law, PV=nRT, relates the volume and pressure of a gas at a given temperature with its concentration].*

• **Results**. 1) When **no agitation** was applied to the bottles, there was no difference in oxygen concentration across stopper types. This was expected since, right at bottling, stopper type can determine the volume and pressure of the headspace, but not the dissolved oxygen in the wine. 2) However, when **agitation** was applied (and oxygen in the headspace was given a chance to dissolve into the bottled solution), the authors observed that **the longer the stopper - and, therefore, the smaller the headspace -, the lower the headspace oxygen concentration**. The exception was the technical stoppers, which had similar heights as natural corks and yet showed higher oxygen concentrations. This indicated to the authors that factors other than stopper height also played a role. 3) The amount of oxygen that each stopper type allowed was, in increasing order: **natural corks (lowest oxygen) < moulded synthetic stopper = screw cap < extruded synthetic stopper (highest oxygen).**

• By carefully monitoring bottling sequence, the authors confirmed that oxygen concentrations decreased as the bottling process advanced. This is because the first solution stream pumped through the bottling equipment absorbs air from pipe-work and other fittings. As the authors note, once the system is stabilized, the oxygen pick-up stops. This justifies the common practice in many wineries of discarding the first few bottles of each bottling run.

• What does this work teach us about stopper selection? The authors make the point that stopper selection should be based not only on oxygen permeability, but also on the amount of oxygen in the headspace at bottling – which, in turn, depends on the headspace volume and overpressure that each stopper generates. Of the stoppers tested, natural corks generated the least oxygen, and extruded synthetic stoppers, the most. To put things in perspective, the authors calculated that the oxygen concentration at bottling in a wine capped with the synthetic stopper or with the screw cap is equivalent to the oxygen entrance in a natural cork during the first 8-10 months. The authors do admit that, if the bottling line is equipped with a vacuum or a modern inert gas system that would completely eliminate air in the headspace, these differences would be minimized. I also wonder if the sensitivity to oxygen pick-up of the manganese sulfate solution is representative of that of a real wine.

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