Contrary to what one might think, color stabilisation can not be completely dissociated with extraction for at least 3 reasons:

1. **actions carried out during vinification** with maceration, as well as the **length** has a stabilizing effect: oxygen additions, délestages, extracted tannins, elimination of the lees …

2. it may be trivial, but it is worth repeating: one cannot stabilize what is not extracted. The **order of what goes into solution of** the different compounds is determined at each instant by specific chemical equilibriums which can recombine in other specific ways. This order of recombination is linked to the different methods of extraction put in place: for example a sulfitic maceration or a thermo treatment, or short maceration in the presence of enzymes lead to completely different rates of dissolution.

3. **the solubility of the compounds** in the must is not infinite. Above a certain concentration, depending on the extraction rates, precipitations, flocculation and crystallization processes occur. The must can be schematically considered like a pocket that is progressively filled up: when this pocket is full, anything else added is either lost or must replace something else.

ICV has started to put into place a color stability test to help wineries implement adequate actions when necessary during the winemaking process. Despite several protocols based on large temperature variations, no test has allowed an anticipation of the overall color loss, even over a very short time frame. Two facts can be extracted from this research:

- the phenomena inducing varying degrees of color stability are very complex
- to improve the color stability, one must use a variety of adapted winemaking practices. Focussing on one element alone is not the best strategy.

Stabilizing the color is more critical when one starts with very little color. One can lose 10 IC points when starting with 30, but when the IC is 10 at the end of the fermentation it is certainly worth implementing certain changes to avoid further losses during the life of the wine.

**Mechanism and questions**

The color of a wine is the result of a large number of molecules represented in the diagrams below. One finds monomers (single molecules) such as:
- pyranoanthocyanins
- xanthyllium

but, mainly polymers or oligomers (several combined molecules) such as:

- combination anthocyanins – anthocyanins
- combination tannin – anthocyanins
- these same molecules linked to an ethyl to make an ‘ethyl bridge’,
- pyranoanthocyanins – tannins,
- portisines.

These simplified diagrams also indicate the color nuances at wine pH for each these compounds.
Free anthocyanins play a large role in ‘young’ wines: after 1 year they will only be 50% of the total percentage, and after 10 years, less than 20% overall.

Also to be considered is that free anthocyanins are particularly sensitive to the pH and SO$_2$ that may be in the wine. The pH is a factor that plays directly in the coloration of certain compounds. Many of the anthocyanins – tannins reactions are pH dependant: the different forms of anthocyanins have different reactivities. It is the pH which determines the chemical equilibriums between the different chemical compounds.

The derived compounds are often more stable over time, more stable with respect to pH and SO$_2$, even if the most recent results show no single rule applies. For example:
- oligomeric tannin- anthocyanin are sensitive to pH as shown in the picture, opposite,
- pyranoanthocyanins, non-polymeric pigments, are quite stable regardless of the pH or the sulfur level.

Color stabilization is the result of the sum of complex phenomena on which the winemaker only has partial control. To have the most color, and for it to be stable, it is critical to extract as much as possible and then to maximize the most stable combinations (extract compounds most susceptible to associate with the anthocyanins), limit the pH shifts as well as other phenomena that will limit precipitation or adsorption.

To summarize:
- have a good management of oxygen additions, as soon as the first recombinations are possible, as soon as alcoholic fermentation starts and especially between AF and MLF where the opportunity to build ethyl-bridges can be done with micro-oxygenation during transfers or with the clicker/dosing.
- The need for micro – oxygenation generally develops for other reasons, organoleptic for example: developing fruity characteristics, limiting the vegetal contribution, increase the volume and mouthfeel and to soften the overall structure…It is necessary to remember at there isn’t one way to work with micro-oxygenation, but many: systematically looking for the notes of ethanal, under the pretext that it is useful for the color stabilization is a mistake on other levels of wine stability.
- The ICV has developed four base models to work with controlled addition of oxygen as a function of the technical and organoleptic objectives depending on the structure of the wine, the varietal…

Whether with a ‘clicker’, sparger or micro-oxygenation, oxygen reacts with several ‘captors’, the main one being the lees. It is important to rack the wine and therefore enable the oxygen to affect the wine more quickly during a treatment. To be remembered, a wine on spent lees is capable of consuming oxygen 4 to 6 times faster than the added oxygen. The INRA measured the oxygen capacity of the wine on lees to be 4 to 30 mg O$_2$ / L more than the same wine without the lees.

Not to forget the role of the temperature on the solubility of the oxygen, and the rate of absorption of the wine: in cold temperature, high solubility and consumption, in warmer temperatures, slow solubility and quick consumption. The most interesting range lies within 16 and 20°C, based on trials.

The graph, taken from work done by Glories, shows the importance and the impact on the mastery of the O$_2$ during ageing, confirming a specific dosage is needed and necessary while still maintaining high values.

- Eliminate the lees early and regularly, both to avoid the adsorption of the colored compounds formed by the vegetal compounds and the yeast membranes, but also to stabilize the pH. This
also avoids localized precipitations by tartaric acid.
Lees are wines that consume a lot of oxygen and their partial elimination allows a more direct and focused application to the wines that react more quickly to the treatment. Rackings between the end of alcoholic fermentation and the beginning of the MLF are particularly important to clarify the wines and to make additions at very favorable time to add oxygen. It is important to note that these rackings do not slow the MLF down (on the contrary!) and they keep the lees in suspension which allows them to autolyze progressively while liberating polysaccharides. These polysaccharides play a role in stabilizing aromatic compounds (study by Doco – Chalier, INRA – UMR SPO, Montpellier – ICV) and contribution to mouthfeel.

- **Having suitable amounts of tannin, in quality and quality** while maintaining the organoleptic profile needed.

**Oxygen additions**
They are necessary during the alcoholic fermentation to limit stuck and sluggish fermentations. These additions have no long-term effect on color-stability, even 4 years later. Therefore, it is between the AF and the MLF that one needs to develop some experience. It is possible to find 2 types of practices worldwide:

- **Regular additions** made with a sparger or a clicker. A sparger (with Venturi effect) can add approximately 4 mg / L d’O₂. With the clicker, playing with the time and pressure, can add less than 0.5 mg / L (with no upper limit). With high addition rates (1 mg / L by day) one can quickly push the sensorial balance too far, so it is important not to overcome the rate of consumption of the wine and its lees.

- **Continuous additions** with micro-oxygenation can be regulated at less than 0.5 and a little more than 150 mg / L per month. It is the technique that is best adapted to a controlled addition of oxygen and also for the stabilization of color.

It is almost impossible to give specific rules and parameters for these additions. The ICV logic is to propose several models such as the one below, and establish a logical strategy from it.

**Preservation du fruit, contrôle de l'ouverture aromatique**

† Syrah types primeur, Grenache de zones tardives
† Macérations préfermentaires à froid

- Éthanol à proscrire, IC et DO 280 (< 60) moyennes = doses faibles
- Accompagnement de l'équilibre réducteur naturel du vin
- Éviter l'amorce de la structuration (durcissement)

The choice of the dosage and the flow rate depend on the turbidity of the wine (presence of lees and high O₂ demanding yeast), the balance between instant color and total polyphenols (the ratio between the two and the absolute values), the objectives for the product, organoleptic deviations to fine and also the temperature.
It is the regular tasting of the wine that helps manage the additions, and the rate. It is therefore critical to define the descriptors and goals of the wine.

Additions can also be done after the MLF.

In this case, the additions are much less significant, in terms of the rate of addition: values are in the range of 0 and 5 mg / L / month. The wine is much more ‘fragile’ and this point and it is important to taste and analyze (IC, SO₂, and microbiology) often to avoid mistakes.

**Sulfur additions**

It is difficult to work with a color objective in mind and then adapt the SO₂ level to that. SO₂ is mainly used for its anti-microbial properties (active SO₂) and anti-oxidant (free SO₂): thus it is the free SO₂ and its relationship with the pH that dictates the SO₂ additions.

The main question is rather: **how to most limit the SO₂ addition to maintain the most color, while keeping the maximum protection of the wine?** Two major points are apparent to improve the wine.

The first is to limit the contaminants: control of the alcoholic and malo-lactic fermentations, perfect hygiene form the vineyard (harvest) to the winery (de-tartrate, cleaning, regular disinfections- planned, noted and controlled by all).

**Limiting the combination of SO₂**: adding sulfite to clean wine (lees, particularly those with plant debris, binds the SO₂ all the while ‘protecting’ the micro-organisms therein) with the necessary and appropriate amount of oxygen.

**Cleaning and racking**

Racking a wine through a basket to allow CO₂ to escape is useful since the dissolved CO₂ slows sedimentation of the lees.

Pectins also slow down the sedimentation of the wine. Adding more enzymes is often necessary on pressed wine, or wine fermented without enzymes. Wine where enzymes have been added will often start clarifying after 48 hours, which allows for a first racking 2 days after a transfer or at the end of the AF.

Between AF and MLF, two rackings are recommended, with a 48 hour interval. This will often results in turbidities of < 500 NTU. If this is not the case, a 3rd racking may be necessary.

After MLF, a racking should be done with a second to follow 7 to 10 days later. The heavy lees will continue to form with an increasingly more infrequent rate. In practice, rackings can be done at 1, 3 and 9 months.

**Exogenous additions of tannins**

The main experimental results do not confirm a net effect on the color of the wine on either poor or excellent quality grapes.

This graph illustrates and evaluation the effects of a tannins addition on a Merlot (that have gone through a thermal treatment). The juice was clarified by flotation. The IC measured at 4 and 12 months show the level of free SO₂ dosed at that moment. The loss of free SO₂ between 4 and 12 months demonstrates the color measured with each experimental parameter. The result shows that more sulfite is
added to the control, and can explain the lower color that is show compared to the others.

First comment, the color drops by approximately 30% between the final AF value and the next one at 4 months into the ageing: not all the color can be maintained.

Second comment, the differences are not significant: all the wines stay in the same category from a visual standpoint. Only the IPT is stronger on the wine with tannin added (40 vs. 37 for the control, thus 10%) right from the end of the alcoholic fermentation.

The next example, from work done by the ICV for the National Tannin Group, confirms these results. Using 6 different enological tannins, there is an immediate effect on the color of the must from the time of addition: effects that are due to the coloring properties of the tannins and also as a result of the synergic interactions between the tannins and the anthocyanins in the must (RFOE, 2002, N°196). These graphs also show a decrease in the color intensity over the course of ageing of the treated wine, and are not significantly less than that measured on the two control wines: there is no stabilization effect, even at elevated doses. Similar results were obtained on wines vinified with traditional maceration.

It is possible to imagine that this is the result of vinification on smaller lots: control of the temperature, better quality of the extraction, adapted oxygen management, proper cleaning regime in place. Even if certain wineries hope to implement all these good protocols, it is rare to find one aware of the proper timing of tannin additions. Either the addition of tannins is only made due to poor grape quality, or perhaps the larger winery has not foreseen the investment of time and resources for any additions. For example, a racking could be postponed by several days, and this delay can result in color loss due to the precipitation of key coloring compounds. In these situations it is possible (although not proven), that an addition of tannin can have an effect.

The dosage is also a factor; does increasing it improve the results? Most dosages used in trials are the recommended dosages. The organoleptic effects are also to be considered: at higher dosages, the astringency and bitterness conferred by the tannins do not integrate well into the wine profile.

**Acidification**

Regarding acidification, 3 years of trials have been done with the R&D at the ICV in long term ageing of Grenache in the Rhône Valley from high pH wines. To take into consideration the effect of pH on color, several organic acids (tartaric, malic and lactic), at several doses and different times (beginning of AF, after AF and post MLF) were tested.
When following good maceration, cleaning, MLF management and sulfiting:

- Acidification had very little effect on the color, regardless of the timing. When there was an effect (less than one time in 3) the intensity is more significant for the additions done at the beginning of the AF, but still a very small difference. The example here (Grenache de Latour de France, PO) shows the impact on the pH with a tartaric acid addition (at authorized levels), but not a significant impact on the color.
- If one compares additions post – AF to post- MLF, there is rarely a difference on the color. If there are differences, they are generally quite weak differences, with a post- MLF being more interesting. For example, on a Grenache from Berlou, +0.2 IC in 2003 when the acidification was done end of AF vs. Post MLF (the difference was not repeatable as it was so small) and -1.9 in 2002 (the biggest difference measured).
- Additions done later are easier to manage from an organoleptic and analytical point of view. Tannins from Mediterranean varietals or vines growing in our climate do not seem to adapt well to early acid additions. This seems contrary to what we see in California or Australia: systematically more astringency and drying is apparent when early acidifications are done here. Australian winemakers, working in the south of France, sometimes make the addition strictly according to the pH meter, sometimes forgetting the reality that different latitudes require different techniques applied.

**Other paths**

At least 3 other trials have been conducted to measure the eventual effects of color stabilization.

- The statistical analysis of oak chips in red wines over several years, conclude that regardless of timing of addition, dosage or toasting levels, there was no effect on the color,
- The management of the MLF as co-inoculation does not improve or degrade the color (IC). Most wineries using this technique are using it for reasons other than color stability,
- Inactive yeast additions, at the recommended dosages do not have a significant impact on the color.

Over long term, the yeast chosen for the alcoholic fermentation will have an impact on the color:

- This could be due to its effect on the pH (D21® systematically results in slightly lower pH’s than other yeast),
- it can also have and effect when the yeast binds more SO2 than others and requires regular additions to maintain the necessary sulfite levels in the wine. It is the metabolites produced by the yeast, and its enzymatic activity which can explain these differences.
- The yeast, once dead, can also adsorb more, or less color from the wine. The photo here shows a wine, 10 years after the fermentation of a botrytized Grenaches with D254® on the left, and K1M® on the right.

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