CONTROL OF THE OXYGEN SUPPLY DURING THE CONDITIONING PART 1: PRINCIPLES AND WINE PREPARATION

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Introduction

The oxidation phenomenon, which is dependant on the presence of oxygen, influences the evolution of wines. A controlled oxygenation contributes to the stabilization of the colour and to a reduction of astringency in red wines as is the case during aging in barriques (1, 2) or in micro-oxygenated tanks. However, it appears necessary to protect white wines which are destined to be drunk young, from oxygen (4, 5). Finally, it is commonly admitted in oenology, that forced oxygenation is not favourable for the quality of the wines. Several authors have shown that 2 mg/L more of oxygen in white wines lead to significant sensorial modifications after a few months (6, 7). Furthermore, the numerous studies conducted to characterize the oxygen supply dissolved during the various operations completed on wines demonstrate that the technological chain which leads to the conditioning of the wine constitutes one of the most critical phases (8-17) even more so once the bottles are sealed, since one can only count on the conservation parameters (temperature, hygrometry, light…) to control the evolution of the wine.

Moreover, other studies (18, 19) demonstrated that the quantity of oxygen stuck in the headspace at the time of conditioning in bottles or in bag in box was often not negligible and was also consumed by the wine over the course of time.

After several brief theoretical reminders, this article will present an assessment of the oxygen supplies dissolved in wines and those stuck in the headspace of the containers, before focalizing on the solutions available to control and reduce these supplies.

General Information

Oxygen Solubility

The gaseous exchanges between the wine and the air are controlled by partial pressure equilibriums. In air, the oxygen represents around one fifth of the volume, its partial pressure is therefore at the normal pressure (1013hPa), at 20 °C, and in comparison to water vapour saturated air, 206hPa. Under these conditions, at the saturation equilibrium in comparison to air, wines contain 6mL/L which is 8,4 mg/L of dissolved oxygen. At a constant pressure, the concentration of dissolved oxygen decreases exponentially with an increase in temperature, whereas it increases proportionally to the pressure. Oxygen as well as nitrogen are not very soluble gases, notably in comparison to carbon dioxide.

Oxygen dissolution

When a gas is placed in contact with a liquid phase, it will diffuse into it progressively. The maximum which can be attained corresponds to the saturation level at the given pressure and temperature conditions. The dissolution speed is described by a diffusion law (Fick's law $dc/dt = k_1 . a (C-C_i)$[1]); it is principally dependent on the gas/liquid contact surface (m^2/m^3) and the initial gas levels in the liquid. Wines enrichment with oxygen from the air will therefore be faster, due to a greater liquid phase surface, since the finesse and persistence of its emulsion with the air will be greater and it is further increased if the initial gas levels are low.

[1] C = concentration du gaz à l'équilibre (liée à la pression partielle par la loi de Henry) ; Ci = concentration initiale du gaz dissous ; k1 = coefficient volumique de transfert de matière ; a = surface spécifique de l'interface gaz / liquide exprimée en m² / m3. C= concentration of gas at equilibrium (linked to the partial pressure by Henry's Law) ; Ci = initial concentration of dissolved gas; k1= volumetric coefficient of matter transfer; a= specific interface surface gas/liquid expressed in m^2 / m^3.

Oxygen consumption

The presence of oxygen in the wines, following its dissolution, is not a stable state over time. The dissolved oxygen is progressively consumed by different substrates, mainly the polyphenols (20). The disappearance of floral aromas is faster under the effect of oxygen supplies even at 15 °C and aromatic alterations occur before chromatic alterations (4).

A wine saturated with air consumes the oxygen in around one to several weeks. The kinetics are faster in red wines than in white wines. In contrary to the dissolution phenomenon, the consumption speed increases as the temperature increases. In oenological conditions it is noted that the oxidation kinetics are very slow, notably when compared to the enzymatic oxidation which occurs in grape must. If the air is renewed, the oxygen consumption continues. The total absorption capacity of wines is very high, it is found between 80mg/L for white wines and 800mg/L for the case of red wines.

Dissolved oxygen in wines

The levels of dissolved oxygen present at a certain time in the wine depends on the dissolution kinetics and on the consumption of oxygen itself. When movement is applied to the wine (pumping, decantation, racking, bâtonnage …) the dissolution kinetics of the oxygen in the air which is in contact with the wine is greater, in general, than the consumption of oxygen by the wine constituents; the levels of dissolved oxygen are measured in the order of mg/L, and saturation could be attained in accordance to the wine surface which is in contact with the air. The oxygen dissolved during the different technological treatments begins to interact with the wine constituents and disappears gradually from the medium, until it reaches a very low level. After which, in a static regime (wines in stocking tanks or in an aging period, as is the case of certain wines in bottles) the dissolution kinetics become inferior to those of the consumption, in a way that the concentrations of dissolved oxygen in the wine are very low, found in the average range of 10 to 40 µg/L. In this situation, the gaseous exchanges are limited to the surface of the wine in contact with a gaseous phase and to the surface in direct contact with the material of the container (barrique, bottle, film…).

Methods and tools for dosing oxygen

An important point of this determination is that it must be completed *in situ,* a characteristic which distinguishes the measurement of dissolved oxygen in wines from the other analytical parameters regularly used for wines.

The significant improvement of the fabrication technologies of polarographic probes and developments for the measurements of micro quantities of oxygen based on the functioning principals of Hersh's galvanic battery for the needs of the nuclear and brewery industries have permitted for the access to methods which can measure in micrograms per liter of dissolved oxygen and in several hundredths of a percent v/v of gaseous oxygen. In the last 4-5 years, a new generation of equipment has appeared which uses luminescence for the measurement principals. Certain of which even allow for a non destructive measurement due to the use of luminescent spots which are glued to the interior walls of a bottle and an optical fiber place in front, on the exterior side.

Hence, the establishment of a unitary operation diagnostic, of an inertion, of a treatment in accordance with the supply of dissolved oxygen or of an assessment of the total oxygen after conditioning (18, 21) is now accessible to all professionals.

Oxygen supplies during wine treatments

The following of dissolved oxygen levels in different wine conditioning centers has allowed for the collection, in oenological situations, of data on the enrichment levels and their variability. The results on the oxygen supplies presented in this paragraph have since been confirmed and verified by (11, 12, 13, 17, 22).

For a given operation (filtration, centrifugation…), the quantities dissolved are very dependent on the conditions under which the various equipments are used for the wine treatments. The enrichment mainly occurs at the beginning of the transferring if the circuit in not inerted or first filled with wine, but it is also occurs at the end of the operation in the case where no particular

precaution is used to control the end of the wine circuit (14). In these different situations the global enrichment during the treatment will depend principally on the volume treated, penalizing equipment and installations which are oversized as well as tanks with low volumes.
Pumping, in industrial condition, dissolves little oxygen, apart from the case of centrifuge pumps with cavities. In a study which compared different pumps, Desseigne (23) signaled that a light aeration of wines at the beginning of the transfer can only be avoided with the used of piston pumps equipment with an “air vacuum”. The continuous registering of data during a centrifugation demonstrates that regular oxygen dissolutions occur at each sequential evacuation of collected sediments in the centrifuge (14). The examination of different sites show that the filtration (alluvion or tangential) can lead to a gain of oxygen of 0,1 to 2,2 mg/L.
Tartaric stabilization is the source of a more consequent enrichment (of 0,6 to 5,7 mg/L noted), in particular in traditional techniques using cold. The setting in motion of cold wine without protection from oxygen during the filtration on kieselguhr and the filling of the crystallizer or the isotherm tank constitute one of the main weak links of the technological chain (15).

The bottling constitutes the 2nd critical point, even more so since after it is no longer possible to intervene directly on the wine (16). Correspondingly, the filling of bag in box containers globally enriches the wine less since it is “under vacuum”. The average supply observed for bag in box is of 0,5 mg/L whereas it is of 1,6mg/L for bottling.
These different possibilities of oxygen dissolution during the conditioning make it not rare to state that conditioned wines contain quantities of dissolved oxygen of between 2 and 4mg/L. And if one adds the oxygen in the headspace after the closing, one obtains enclosed quantities of oxygen close to 6mg for bottle lots of 75cL (19) and 6mg per liter of wine for those in bag in box lots of 3L (18).

	Average supply of dissolved oxygen in mg/L			
Operations	**Vidal et al. 2001, 2003, 2004** (14, 15, 16)	**Valade et al. 2006** (12, 13)	**Castellari et al. 2004** (11)	**Alinc et al. 2008** (17)
Decantation from below (15-20°C)		0,30	0,37	
Decantation from above(15-20°C)		3,10	0,37	
Decantation from below (5-10°C)			1,30	
Fining and removal fining agents				1,36-1,47
Pumping	0,1 à 0,2		0,10	1,41
Barrique assembly			1,75	
Continuous alluvion filtration	0,70	0,70	0,24	0,79
Sheet/Plaque filtration	0,20	0,50	0,04	
Cartridge filtration	0,10		0,06	
Filtration tangentielle Tangential filtration	1,50		0,20	
Centrifugation	1,00	0,95	1,20	
Refrigeration			1,30	
Exchanger heating			0,15	
Continuous THK stabilization	2,40	1,20	4,00	
THK stabilization by stabulation	2,38 + 5,70*			
THK stabilization by contact	2,43			1,66
Electrodialysis	1,30		0,28	
Fixed dissolution bottling ………… gaseous mg/bottle	1,60 0,38 à 4,3	2,0 à 7,0**		1,00 0,27 à 1,86
Bag in box packaging	0,50			

Table 1 : Bibliographic summary of the oxygen supplied during different operations
** 5,70 mg/L : estimation dissolved oxygen consumed during the stabulation.*
*** On sparkling wines, oxygen consumed by yeast.*

Evolution of dissolved and gaseous oxygen in conditioned wines

From the moment that the wine is conditioned, the levels of oxygen of the gaseous and liquid phases diminish during the first two months. The kinetics are dependant on the temperature (24). Then, this reduction slows before the concentrations progressively stabilize to values lower than 0,1mg/L for the wine and at 1% v/v for the headspace. Furthermore, whichever wine is studied and whichever the analysis date (even on samples of 39 years), the percentage of oxygen saturation of the headspace is always superior to that of the wine. This signifies that because of the search for equilibrium, the transfer of oxygen always occurs from the headspace towards the wine (case for upright bottles). Thus, as the wine bit by bit consumes the oxygen it contains, there is a dissolution of the oxygen present in the headspace in the wine by the contact surface of gas/liquid.
During the bottling, right after the closing, the quantity of oxygen trapped in the headspace is not negligible. In the case examined by Vidal and Moutounet (19), it varies between 0.38 and 3.58 mg/bottle and depends mainly on the type of equipment used for the closing, the volume of the headspace and the technique used in order to protect from oxygen during the closing. A further experiment showed that the stoppering without vacuum and without gas inertion is responsible for a net increase in the quantity of oxygen which can reach 4,3mg/bottle. Also, in this case, as for that of wines rich in carbon dioxide in which a part of this gas will migrate into the headspace, the overpressure applied can provoke a faster dissolution of oxygen.

During the first period, the oxygen is being consumed and oxidation reactions take place. One can assume that the speed of these are governed by the oxygen contained in the bottle at the bottling time; to which a few milligrams of oxygen trapped in the stopper could be added and used up over the following first 20 days, as written by several authors (25, 26). The kinetics of these reactions decrease as the oxygen is progressively rarer. The average experimental speed of oxygen consumption is superior to several dozens of micrograms/bottle/day during the first 30 days at 15°C and this falls at the start of the second month to values lower than 10 µg/bottle/day. This result is coherent with the speed of diffusion across the stopper in the order of µg or tenths of µg/bottle/day recently described (25, 26). This shows also that at this temperature, the penetration kinetics across the stopper are lower than the dissolution and consumption kinetics inside the bottle, since if it were not the case one should observe a progressive enrichment in oxygen.

An experimental study, in press, completed on a bottled Sauvignon white wine, exemplified the direct impact of inadequate bottling conditions (high content of dissolved oxygen and stoppering without vacuum or inert gas) on the total oxygen quantity and resulting free SO_2 loss. In fact, for bottles containing 5,85mg of total oxygen right after bottling, the free SO_2 losses were increased to 44% after one month whereas on bottles containing 1,67mg, the same losses were only 12%. At the end of 18 months of conservation at 17°C, the average content of free SO_2 of the bottles bottled under adequate conditions was of 20 instead of 10mg/L as in the other case.

These phenomena described for bottled wines were also observed for bag in box (18), but with an essential difference. Even though the oxygen supplied during the conditioning is lower than in bottles, once almost all the oxygen trapped at the beginning has been consumed, the levels of the oxygen in gaseous phase and in particular in dissolved phase stabilize to levels clearly superior to those found in bottles. This confirms that the gaseous exchanges are more intense in bag in box, since the whole film-tap system is more permeable to oxygen than a stopper or capsule. The greater diffusion of oxygen is responsible for losses in free SO_2 and for a more apparent evolution of the colour. These observations can vary with the permeability properties of the films used for the bag in box.

Solutions to reduce oxygen dissolution in wines

Wine Deoxygenation
Deoxygenation consists of the desolubilization of the excess oxygen in wines by injecting microbubbles of neutral gas. These microbubbles are generated by a sinter with a porosity of 2 to

20 microns which is placed in an injector installed at the exit of the transfer pumps. During the process, it will be the oxygen molecules that will be eliminated first and preferentially. The carbon dioxide, clearly more soluble in the wine is desolubilized more difficultly. The flow of gas in decarbonation is much higher than in deoxygenation. The flow of neutral gas is in general equal to 10% of the flow of the pump transferring the wine. This value must be increased if the dissolved oxygen content is higher than 5mg/L (27). Pouchain and Cazorla give an equation that allows for the modeling of a deoxygenation operation, as well as the technical elements necessary for the calculations (porosity of the sinter, gas flow…) (28). Usually, it is possible to eliminate from 80 to 85% of the dissolved oxygen with a nitrogen consumption in the order of 0.5 to 1liter/liter of wine and with a length of tubing after injection of around 25m.

The gas/liquid transfers obtained inside an ejector, in which the wine arrives by a tube in a chamber where the wine is mixed with inert gas before the diffusion, present an around 20% higher efficiency than that observed in a contact with classic bubbling by sinter (28).
As for deoxygenation by sending nitrogen by a stirring rod, it is less efficient. In fact the quantity of gas used is significant, there is loss of aromas due to the agitation, and there is the elimination of 20% of the oxygen at best (Linde data).

Recently, membrane contactors have appeared on the market. These are envelopes which contain concave microporous hydrophobic fibers which have the advantage of possessing a very large interface for gas/liquid contact due to the uniformly partitioned pores found along the fiber (28). In theory, their large exchange surface should allow them to deoxygenate efficiently notable quantities of liquid, given that the liquid be sufficiently limpid so as to not obstruct the membranes. Trials completed on other liquids have enticed the industry to plan future experiments on wines.

Neutral Gas Quality

All will depend on the dissolved CO_2 content that one wants to maintain in the wine. In fact, the more one wants to maintain this dissolved gas, the more its percentage in the inerting gas must increase (between 20 and 50%), according to the calculation established by Lonvaud-Fumel (29). However, as verified by Falkenburg (30), as the percentage of CO2 in the inerting mix increases, the deoxygenation is less efficient. Following several trials, this author concluded that a gaseous mix of 70 % N_2 and 30 % CO_2 (at a gas flow equal to 25L/min and a transfer flow of wine of 180hL/h) is the best compromise for the deoxygenation of a still wine without reducing in a significant manner the dissolved carbon dioxide content of the wine.

Tank inertion

The inertion consists of completing a clearout of the gaseous space with neutral gas under low pressure in order to replace the air by the neutral gas. An argon inertion theoretically requires an application limited to 1 times the volume to inert instead of 3 to 4 times as for nitrogen. A mix of 80% argon and 20% CO_2 would permit an efficient inertion with a « piston effect » (which is less the case for a mix of 80% nitrogen and 20% CO_2) while limiting the decarbonation risks (as with pure nitrogen) and overcarbonation risks (as with pure CO_2). The decantation of the wine would need to be associated with a neutral gas supply equivalent to the volume of wine decanted.
A inertion trial with the aid of a floating-diffuser of gas (Purgal® Air Liquide) on a tank filled to 120hL on a total volume of 140hL conducted at the INRA Gruissan showed that the residual oxygen levels in the gaseous space lowered to below 0,5% v/v with pure CO_2 or with the mix of 80 % argon and 20 % CO_2, whereas it was difficult to lower below 2% v/v with nitrogen. However, pure CO_2 does not allow for the stocking of even white or rose wines over a longtime without overcarbonation. In this particular example, the gas consumption was 2 times less high to obtain 2% of residual oxygen than that with nitrogen and the purge time was 2,5 times less long (20 instead of 50min) (31).

The winery of Sieurs d'Arques in Limoux injects CO_2 for 6 min at the valve of the pump and before the start of the transfer in order to inert the circuit which follows (40-60 m of supple tubing of 70mm

diameter) and the reception tank (160-180 hL) by forming a carpet of CO_2 of 50 cm to 1m high, enough to lower the gaseous oxygen content below 5% v/v. The gas injection pressure does not pass 200kPa, in order to avoid gaseous movements which would destroy the CO_2 carpet. In these operation conditions, the average supply is situated around 0,1mg/L for an initial dissolved oxygen content of below 1mg/L. This practice confirms the observations made by Vidal et al. on the pumping (14).
Allen (32) referred that in the case of a tank being emptied, usually closed, the reoxygenation of the gaseous spaces is respectively of 0.3%, 1% and 2%/day for argon, carbon dioxide and nitrogen. These data demonstrate that outside of argon use, it is important to add gas during the emptying every 2-3 days.

With regards to the inertion of circuits, if the diameter of the tubing which directs the neutral gas is too small, the consequent losses in flow can lead to a depression at the end of the line and cause some oxygen dissolution. It is therefore necessary to envisage a resting pressure for the gas sufficient to avoid this problem.

Sources of Inert Gases

Putting aside systems which provide inert gases from the bottling frames or from nitrogen generators, dry ice gel remains a popular choice, since it is simple to use. It is fabricated by the compacting of dry ice with the aid of hydraulic presses and is extruded in the forms of pellets or sticks. Theoretically, for 1000L of gaseous space, 2kg/day are needed. In practice however, one must multiply this quantity by two, knowing that the product lasts only around 12 hours. This is why it is advisable to use it for short stocking times (33).

Some Data about the Costs

On a base of 100 for a m^3 of nitrogen in a B50 bottle, CO_2 is worth 99, the mix 80% nitrogen and 20% CO_2 is worth 122, argon is worth 216, the mix 80% argon + 20% CO_2 is worth 226 (source Messer). The producers of Plaimont estimated that the cost of only the neutral gas consumption starting from the vinification until the bottling was of 1€/hL (La Vigne oct. 2006), for the same use the domain de La Baume tabulated a cost of 0.5€/hL in 2001 (34). The cooperative winery les Sieurs d'Arque in Limoux tabulate this cost at 0.8€/hL in 2007 (0,3 during the vinification and aging and 0,5 for the bottling). The use of inert gases is therefore to be reasoned accordingly to the assessed value of the final product.

Pumping and decanting

The critical steps of the pumping and decanting operations are the beginning and the end of the operations. For continuous functioning, these operations do not enrich the wine. The enrichments are therefore due to the taking in of air at the beginning and the end of pumping, and to the dissolution of air in the volume of the circuit where the wine is in contact with the air in the tanks at the departure and arrival. It is equally to be underlined that if the arrival recipient is filled from the top, the height of the fall and the function of the tube position, significantly influence the dissolution.

The linear speed of the liquid is considered as a parameter which can lead to turbulences in the canalization and can induce some oxygen dissolution (35). These authors show that the optimal dripping speed which is not turbulent is of 0,1m/s, that which is incompatible for industrial treatments, unless very large canalization segments are used. They define a maximal acceptable speed to be 1m/s to 1,5m/s, using the formula $V_1 = 35,4\ d/a^2$ to determine the linear speed V_1 (in m/s) of a liquid according to the dripping speed d (in hL/h) and to the canalization diameter a (in mm).

In-line pushing, also called shard scraping, allow the recuperation of some of the product without oxygenation (the line is maintained with nitrogen), the limitation of wastes and the separation of lots during a transfer or a conditioning.
According to the controls completed by Oenodev, a decantation of barriques and filling by the top of the destination tanks by corkscrew pumps instead of piston pumps allows for the limitation of the oxygen supply to 1,2-2,4 mg/L instead of 4,3mg/L.
Working in a protected environment lengthens the operation time. While 35min are sufficient to discharge a reservoir in classic conditions, 1h30 are necessary with respect to the procedures, being 30-45min for the inertion of the circuit and the tank and 30-45min for the emptying of the circuit and of the reservoir (Grands Chais de France, La Vigne oct. 2004).

Operation	Advice	Objective
Pumping	Place the pump close to the departure tank	Limit the aspiration length
	Promote corkscrew pumps	Induces a less turbulent regime than piston pumps notably at the beginning
	Avoid centrifuge pumps	Avoid the cavitation risks at the start or at the restarting after a stop. Very penalizing for the oxygen supply.
	Limit angles, joints and suspended tubes	Obtain a better inertion and filling of canalizations
	Inert tubes and tanks before the start	Reduce the gaseous phase oxygen in contact with the wine to limit its dissolution
	Inject nitrogen for the first hectoliters and to push out the last. Pump at a slow speed at the beginning and end of the transfers, when the tubes are not full of wine	Limit an increase in the supply at the most critical moments.

Table 2: Practical advice to reduce the oxygen content during the pumping.

Fining and Removal of Fining Agents
According to the controls executed by the BIVB (22), the average supply observed during fining operations is of 1,36mg/L with a standard deviation of 0.83. Despite whether aeration is practiced or not, the operation conditions are the main source of heterogeneity (volume of wine to be treated, dimensions of the tank…).
For the aim of a maximal protection of the wine from oxygen, a reduction of the supply can be obtained essentially by simple pumping while reducing as much as possible the falling height of the wine in order to incorporate the fining agents; all this with the stirring of the wine with the help of a homogenization cane seems to be the most adaptable practice against oxygen enrichment.
The removal of the fining agents being no more or less than a decantation, see the paragraph on the pumpings-decantations.

Clarification Procedures
The oxygen supply for a filtration on kieselguhr, under usage conditions without any particular protection, varies according to the volume of wine filtered on the same cake. The enrichment of the wine occurs particularly in the first hectoliters due to the oxygen found in the porosities of the kieselguhr and at the emptying of the compressed air vacuum.
As for tangential filters or plaques, the dissolution mainly occurs at the filling and emptying of the equipment.

Adding nitrogen to the evacuation mechanic of the dregs in a centrifuge can permit to lower the supply which however is limited to some hundred microliters per liter.

Operation	Advice	Objective
Filtration on kieselguhr, tangential filtration, centrifugation	Inject nitrogen during the filter use particularly during the passage of the first hectoliters.	Limit an increase in the supply at the start, and avoid the need to deoxygenate the wine
	Empty the filters with nitrogen use	Limit an increased supply at the most critical moments
	Retro-filtration with nitrogen on tangential filters with continuous alimentation	
	Remove sediments with nitrogen application for the centrifuge	
	Filter, centrifuge the lots of greater volumes	Reduce the negative impact of the start and end on the total volume treated

Table 3: Practical advice to reduce the oxygen content during the clarification operations.

Tartaric stabilization

The enrichment in oxygen by electrodialis treatment is more weak, as much as the equipment has been sufficiently inerted in order to decrease below 2% v/v of trapped oxygen. (15).

For traditional solutions, the inertion of the crystallizer and of the isotherm stabilization tanks before the arrival of the cold wine, and their maintenance with neutral gas up until the total emptying of the tank, as well as an injection of gas during the filtration make up the means to efficiently work against a potentially great enrichment of the wine. The injection of nitrogen during the pushback of the filter also allows for the deoxygenation of the wine (15).

The second half of the article, dedicated to the conditioning and with the bibliography, will be published shortly on Infowine.com

Keywords: dissolved and gaseous oxygen, inertion, SO_2, packaging, bottle, bag-in-box.

Synthesis:

The adaptation of methods for measuring dissolved oxygen in any type of container (thanks to the creation of gas tight circuits) and the continuous control of more than 14.000hl of still wine of all kinds during their conditioning (reception, treatment, bottling or bag in box packaging) have made it possible to characterize oxygen additions during the various operations which the wine undergoes and to propose solutions in order to reduce them, and to limit the use of antioxidants (SO2, ascorbic acid) while preserving the aromas as well as possible and by lengthening the shelf life of conditioned wines.

In general, the final total pick-up depends mostly on the relationship between the volume of wine to be treated and the volume of the circuit.

The most important enrichments occur particularly during the operations of cold tartaric stabilisation and during the bottling, especially if no precautions are taken to protect the wine from the oxygen in the ambient air.

As for the oxygen trapped during conditioning in the headspace, the tests carried out show that the quantity of oxygen trapped in the headspace right after stoppering varies from 0.38 to 3.58 mg per bottle, to which it is necessary to add the dissolved oxygen in the wine whose measured values vary from 0.5 to 6 mg/L.

The rationalization of the operating conditions, the judicious use of neutral gases especially at the beginning and the end of operations, as well as the inertion of bottles before filling and right before closing make it now possible to control and significantly decrease the oxygen pick up during all the operations related to conditioning. The objective is to go below one milligram of total oxygen trapped in bottle or bag in box has already been reached in certain installations.

Finally, the conditioners will continue to have more possibilities to put in practice a qualitative evolution of the desired wine and this also for the closures, which have had significant progress in their homogeneity and their oxygen permeability levels (Oxygen Transfert Rate).