Characterization of Degassing Equipment and Its Impact on Wine Chemistry

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Abstract: Carbon dioxide, free sulfur dioxide and dissolved oxygen are key parameters monitored throughout the winemaking process or at bottling to ensure the wine delivers the winemaker's intended style and aging potential and that it is adequately protected from destructive oxidation effects or microbial spoilage. The aim of this study was to characterize three carbon dioxide degassing devices used in amateur winemaking and their impacts on sulfur dioxide dissipation and oxygen uptake. The results demonstrate that at the test temperature, the stirring rod degasses a single carboy most rapidly but that it dissipates free sulfur dioxide and dissolves oxygen to a greater extent than the Gas Getter and vacuum pump.

Key words: wine degassing, home winemaking, carbon dioxide, sulfur dioxide, dissolved oxygen, Gas Getter

Introduction. Kit wines are very popular with amateur winemakers, who make wine at home or at brew-on-premise (BOP) operations, because the kits are easy and relatively inexpensive to make. Kit wines don't require the investment in equipment in making wine from grapes, they yield consistent and reproducible quality, and they can be bottled in as little as four weeks for entry-level kits. Premium kit wines are generally ready for bottling in as little as eight weeks.

Kits are manufactured with the objective of reducing or eliminating altogether any possibility of user errors; however, the short winemaking cycle poses several important challenges to kit manufacturers.

1. Excessive residual carbon dioxide (CO_2) from yeast and malolactic fermentations can prevent proper clarification by fining agents, such as kieselsol/chitosan. Particles in the fining agent suspension will act as nucleation sites for dissolved CO_2 gas and cause an increase in gaseous kinetic energy that will prevent precipitation of targeted colloidal matter.

The amount of CO_2 gas in wine post fermentation is typically in the order of 2000 mg/L (Peynaud, 1987). Residual CO_2 gas is usually of no concern in commercial wines as these are processed with a longer lead time using equipment and methods (e.g. pumping, racking, filtering) that hasten gas dissipation into the atmosphere.

The rate of dissipation is a function of the solubility of the gas during processing and aging, and solubility is a function of temperature and alcohol concentration: The higher the temperature, the higher the rate of dissipation (i.e. the lower the solubility) and similarly, the higher the alcohol concentration, the higher the rate of dissipation.

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2. Wine bottled with excessive CO_2 gas will be perceived as flawed because it will impart a slightly effervescent sensation akin to carbonated mineral water and is generally unsuitable in dry table wines. It will also increase acidity due to the higher carbonic acid concentration, which can then disrupt the wine's balance and make the wine seem overly dry by offsetting any residual sugar content and, in the case of reds, it can increase bitterness of tannins (Peynaud, 1987).

3. Excessive CO_2 gas in bottled wine can cause instabilities, such as renewed cloudiness, and possibly exert excessive pressure on the glass and cork, and result in bottle breakage or corks popping out.

To avoid these problems, winemakers degas wine prior to bottling by using the handle of a long plastic spoon, a drill-driven stirring rod with flip paddles, a vacuum pump, or the Gas Getter. The first two devices are best suited for small-scale winemaking as they can only be used on one carboy at a time. A vacuum pump is used to degas a single carboy but it can also be used on multiple carboys at once when fitted with the proper degassing attachments. The Gas Getter is best suited for BOP winemaking because it can degas up to 24 carboys at once.

A small amount of CO_2 gas is however necessary to maintain freshness and balance as well as to help volatilize aromas so they can be smelled by the taster. Every style of wine has an ideal residual CO_2 range, depending on wine chemistry (i.e., acid, polyphenol and alcohol concentrations) and the winemaker's preference. Although one author recommends a residual CO_2 level less than 100 mg/L before bottling for all wines (Peynaud, 1987), more typical ranges are: 200–500 mg/L for aged red wines and 500–1800 mg/L for lighter reds and white wines (Müller-Späth, 1982; Boulton et al., 1996).

But degassing, or any wine processing for that matter, should not adversely impact sulfur dioxide (SO_2) protection against oxidation and microbial spoilage, introduce excessive oxygen (O_2), or adversely impact aromas and flavors.

Table 1 lists solubility, boiling point and Henry's Law constant (k_H) data for molecular O_2, CO_2 and SO_2. SO_2 is the most soluble and the least volatile of the three gases, while O_2 is the least soluble and the most volatile; CO_2 is situated between these two compounds.

Compound	Solubility* (mole fraction)	Boiling Point* (°C)	k_H** $\left(\frac{mol}{L-atm}\right)$
Oxygen (O_2)	2.3×10^{-5}	–183	1.3×10^{-3}
Carbon dioxide (CO_2)	6.2×10^{-4}	–78***	3.4×10^{-2}
Sulfur dioxide (SO_2)	2.5×10^{-2}	–10	1.2

Table 1 Solubility and boiling point values and Henry's Law constants of gas compounds in water at 25°C and one atmosphere.

*Source: Haynes, W.M., ed. *CRC HANDBOOK OF CHEMISTRY AND PHYSICS, 92ND EDITION, 2011–2012*. Boca Raton, Florida: CRC Press, 2011.
**Source: Sander, Rolf. *Compilation of Henry's Law Constants for Inorganic and Organic Species of Potential Importance in Environmental Chemistry*. Mainz, Germany: Max-Planck Institute of Chemistry, 1999.
*** sublimation point

Total sulfur dioxide (TSO_2) represents the sum of free SO_2 (FSO_2), resulting from yeast fermentation and sulfite additions, and bound SO_2 (BSO_2) concentrations. Bound SO_2 is the result of free SO_2, and more specifically bisulfite (HSO_3^-), binding with other compounds, such as carbonyl compounds and polyphenols. As free SO_2 binds, the concentration of FSO_2, or [FSO_2], decreases, [BSO_2] increases and [TSO_2] remains constant. However, as molecular SO_2 is volatile, some free SO_2 will be lost to the atmosphere, especially during wine processing and at higher temperatures. Some SO_3^{2-} may also be lost as the result of oxidation to SO_4^{2-}. Therefore, the measured [TSO_2] can be expected to be less than the theoretical [TSO_2].

The rate at which O_2 dissolves into wine is a function of temperature and surface area and, as per Henry's Law, is directly proportional to the partial pressure of O_2 above the wine. The greater the surface area of wine exposed, the faster O_2 will dissolve. The industry-accepted norm is to bottle wine with no more than 2 mg/L of dissolved oxygen (DO). It is important to remember that O_2 dissolves at the surface and diffuses into the volume. Procedures such as stirring, racking and pumping inevitably increase the rate of O_2 uptake (Bartolini et al., 2008).

The objective of this study is to characterize the three main degassing tools used in home winemaking, their CO_2 degassing effectiveness, and their impact on FSO_2, TSO_2, and DO. Assessing aroma and flavor impacts can be highly subjective and is therefore not part of this study; aroma and flavor intensities can be measured with much more sophisticated methods and equipment.

Materials and Methods

Wine Samples. A white wine varietal was selected for this study to reduce polyphenol effects inherent in red wines. Two 23-liter (6-gallon) batches of RJ Spagnols' 4-week Grand Cru Pinot Blanc fermented to dryness, blended, sulfited with 7.2 g of potassium metabisulfite (which yields approximately 80 mg FSO_2/L) and then divided into three equal batches into 11-L (2.9-gal) glass carboys. Leftover wine was used to top up samples under test with the Gas Getter and vacuum pump. Samples were kept and tested at 13°C (55°F).

Test Equipment. A stirring rod equipped with two paddles that flip up when activated with an electric drill was used. The number of rpm on the electric drill was not measured.

A Gas Getter model 905-1 (capable of degassing up to four carboys), supplied by Rhone Lahr (Cilla's Villa, LLC), with three ports shut off, powered by 65 psi of compressed air by a DeWalt 1.6 hp continuous, 200 psi, 15-gallon workshop compressor.

A vacuum bung attachment powered by a 1/6 hp TLEAD vacuum pump, model AS20 supplied by Blichmann Engineering, with a vacuum rate of 600 mmHg (11.6 psi) air input per min/L.

Instrumentation. A Veitshoechheim CO_2 cylinder was used to measure residual CO_2. A Hanna SO_2 Mini Titrator Model HI 84100 was used to measure both FSO_2 and TSO_2. An Extech Dissolved Oxygen Meter Model ExStik DO600 was used to measure DO. A Hanna Digital Thermometer Model HI 98501 was used to measure sample temperature.

Test Procedure. For each batch, residual CO_2, FSO_2, TSO_2 and DO concentrations were measured prior to degassing. Each batch was degassed at 13°C with one degassing test device and 150-mL samples of wine were retrieved at regular intervals and measured for CO_2, FSO_2 and DO concentrations. Sample temperatures were measured and values used to compensate measurements where temperature-compensation was not provided by the instrument in use. Between each degassing interval, the wine removed for testing was replaced with the reserved wine in order to maintain a constant test volume. The test was concluded when residual CO_2 was close to 500 mg/L or could no longer be dissipated. At the conclusion of the test, CO_2, FSO_2, TSO_2 and DO concentrations were measured again.

Test Errors. Accuracy and precision of tests was limited by available instrumentation and analytical methods. Test results are provided without accuracy/precision analysis.

Results and Discussion

Residual CO_2. Figure 1 illustrates the rate of CO_2 dissipation for each device under test showing a best-fit line through the test data curves.

The stirring rod degassed the wine at a rate of approximately 29 mg/L/min at 13°C. The Gas Getter and vacuum pump demonstrated similar rates in the range 3–4 mg/L/min with residual CO_2 leveling off given the sample test temperature, and equipment and methods used. A more powerful compressor is recommended with the Gas Getter, and this equipment and the vacuum pump require the carboy to be rocked slightly to help release CO_2.

These results are in line with expectations that the stirring rod degasses faster as it stirs the whole wine volume while the Gas

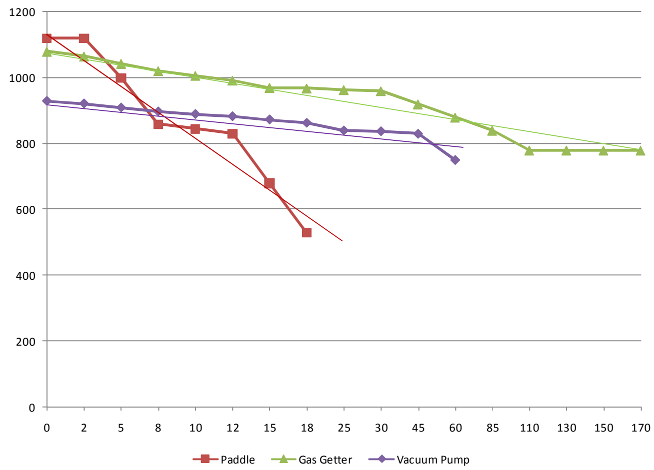

Figure 1 Degassing effect at 13°C on residual CO_2 concentration (mg/L) over time (mins) using three common devices used in home winemaking.

Getter and vacuum pump decrease the partial pressure above the wine and, without agitation, have little impact on the rate at which CO_2 diffuses through the bulk of the wine.

Free SO_2. Figure 2 illustrates the rate of SO_2 dissipation for each device under test showing a best-fit line through the test data curves.

The stirring rod dissipated SO_2 at a rate of approximately 0.8 mg/L/min at 13°C. The Gas Getter and vacuum pump demonstrated similar rates in the range 0.1–0.2 mg/L/min. And although the net difference in [FSO_2] between the start and end of the tests is higher for the stirring rod, the differences are within tolerances of instrumentation and methods used and are therefore not significant. [FSO_2] dropped by 12, 8 and 4 mg/L for the stirring rod, Gas Getter and vacuum pump, respectively.

These results are in line with expectations that the stirring rod dissipates SO_2 at a faster rate for the same reasons it is more effective at CO_2 degassing.

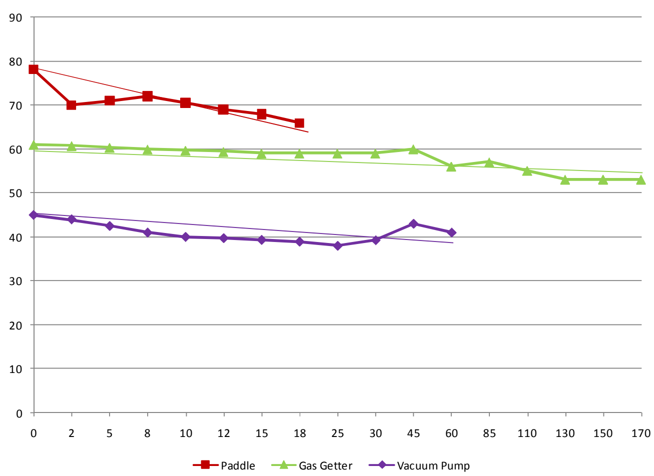

Figure 2 Degassing effect at 13°C on free SO_2 concentration (mg/L) over time (mins) using three common devices used in home winemaking.

Total SO_2. Figure 3 illustrates TSO_2 concentrations of samples at the start and end of the tests used by each device under test.

Based on FSO_2 results discussed above and the same order-of-magnitude drop in [TSO_2] given the tolerances of instrumentation and methods used, it can be concluded that free SO_2 dissipates to the environment, i.e. it does not become bound, resulting in a commensurate drop in TSO_2 concentration.

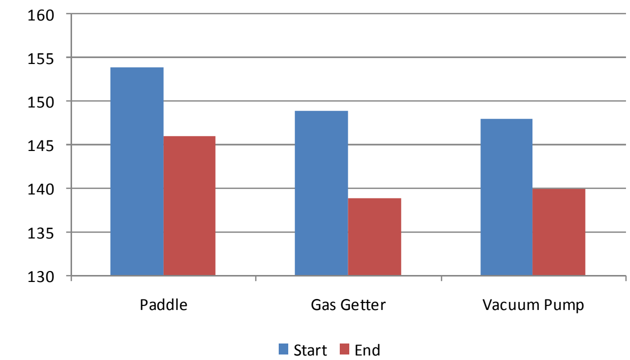

Figure 3 Degassing effect at 13°C on total SO_2 concentration (mg/L) at the start and end of the test using three common devices used in home winemaking.

Dissolved Oxygen (DO). Figure 4 illustrates the rate of O_2 dissolution into wine for each device under test showing a best-fit line through the test data curves.

The stirring rod injected O_2 at a rate of approximately 0.08 mg/L/min at 13°C. The Gas Getter and vacuum pump demonstrated similar rates in the range 0.006–0.008 mg/L/min.

These results are in line with expectations that the stirring rod injects more O_2 given its vigorous treatment throughout the volume of the wine. It was not expected that the Gas Getter and vacuum pump would inject any O_2 into the wine; and the observed increases may well have been due to the procedure of topping up carboys with the reserved wine.

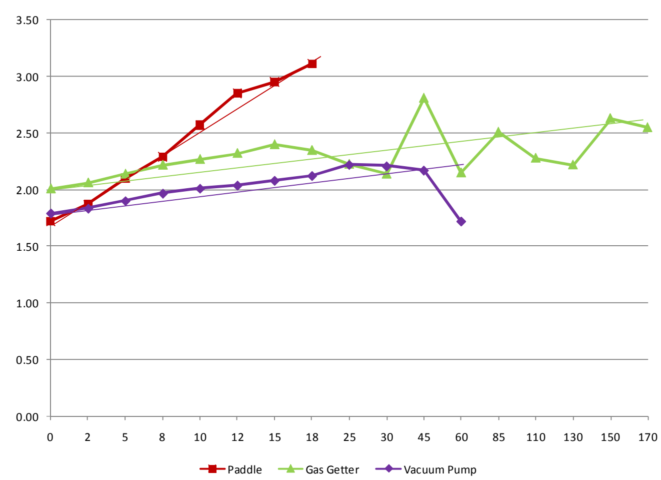

Figure 4 Degassing effect at 13°C on dissolved (DO) concentration (mg/L) over time (mins) using three common devices used in home winemaking.

Conclusions

This study concludes that the stirring rod can degas a single carboy most rapidly at 13°C and down to any desired residual CO_2 concentration; however, excessive oxygen may be injected with detrimental effects on wine quality if the wine is degassed excessively. The Gas Getter and vacuum pump used for this study took longer at the test temperature and leveled off at higher levels. More powerful equipment is available to speed up degassing with these devices. In this regard, the Gas Getter and vacuum pump are more advantageous as they can degas multiple carboys in BOP operations.

The Gas Getter and vacuum pump dissipated less FSO_2 and at a lower rate than the stirring rod. In all cases FSO_2 was lost to the environment, i.e. it did not become bound and no longer contributed to TSO_2.

The stirring rod did however inject O_2 at a higher rate than the Gas Getter and vacuum pump.

To eliminate the loss of free SO_2 with the Gas Getter and vacuum pump, sulfite can be added once degassing is completed. This is not recommended for the stirring rod given the higher rate of O_2 uptake that may negatively impact the wine without SO_2 protection.

One advantage of the Gas Getter and vacuum pump is that, since there is no foaming, carboys can be left almost full while degassing; the stirring rod requires that up to 2 L (½ gal) of wine be removed to accommodate foaming.

This study should be repeated using a more powerful compressor and Gas Getter unit along with a nucleation device in the wine to hasten degassing. Screws dropped at the bottom of the carboy could serve as nucleation devices that will hasten CO_2 gas to nucleate and dissipate at a faster rate.

Similarly, the study should be repeated using a vacuum pump but rocking the carboy to hasten CO_2 dissipation.

This study should also be repeated using red wine to characterize the behavior of degassing devices and their impacts on wine chemistry in the presence of higher polyphenol contents than what is found in white wines.

In a separate study, turbidity testing should be performed on the finished wine to determine the amount of dissolved solids that could potentially nucleate, or possibly inhibit, the release of dissolved gases. This would help ensure uniformity between test batches.

This study did not look at aroma and flavor impacts. A follow-up study should be performed with a panel of tasters to determine any aromatic and taste differences among wines treated with the different devices.

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