Investigating the Effects of Oxygenation on Redox Potential & Fermentation Kinetics

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INTRODUCTION

Every year the wine industry faces significant financial losses as a result of stuck fermentations and the presence of reductive faults in finished wines. Currently, most wineries rely on temperature and °Brix metrics to monitor the progress of a fermentation. While these parameters are useful for tracking fermentation progression, they do not reflect the chemical and metabolic status of a fermentation in real time.

Redox potential, or Oxidation Reduction Potential (ORP), is an emerging process parameter in the wine industry, that has long been utilized for tracking fermentations in the biofuel, wastewater, dairy and food safety industries[1]. The parameter offers a valuable real-time indicator of redox status within a fermentation, which correlates with yeast metabolism, fermentation kinetics, and hydrogen sulfide production[1,3,4].

Aeration is a method commonly used to raise the redox state[2], which is also compatible with the wine making process and available to most winemakers. Controlling redox is a useful tool as it has the potential to facilitate faster and more robust fermentations as well as help avoid costs associated with problematic or stuck fermentation[3]. Finally, redox potential could be used to make decisions around aeration to prevent the formation of unwanted compounds associated with reductive fermentation conditions, ultimately improving wine quality.

The goal of this study was to gain a better understanding of how oxygen introduction, at various times and amounts during fermentation, affects redox status and how this is linked to overall fermentation outcomes. Fermentation kinetics, cell density and preliminary wine chemistry analysis was used to assess these outcomes.

MATERIALS & METHODS

This study consisted used 950 mL ferments, that received aeration throughout 0 (control), 16, 32, 48, 64 and 80 hours of the fermentation. Fermentations were carried out in 1 L bioreactors with constant stirring and temperature control. A white juice concentrate diluted to 24°B (3.16 pH, 6.37 g/L TA, 255 mg/L YAN) was used as the juice medium and was inoculated with commercial EC1118 yeast. Fermentations were run at 23°C. Hamilton ORP probes were used to collect redox data continuously throughout fermentation. Redox curves were generated from 1-minute intervals.

Redox was controlled to a -60 mV setpoint via aeration. Air was sourced from a cylinder and delivered at a rate of 150 mL/min as needed to maintain the ORP setpoint. Manual °Brix measurements were taken three times a day. Cell counts were conducted each day and at time of fermentation completion. Samples for wine chemistry were taken from the initial juice, from each vessel when the redox minimum was reached, and upon fermentation completion. Organic acid analysis was generated via HPLC[5].

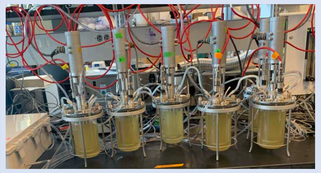
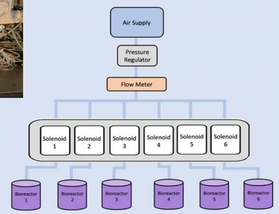


Figure 1a. Experimental set-up in lab.

Figure 1b. Air delivery schematic for redox control.



RESULTS

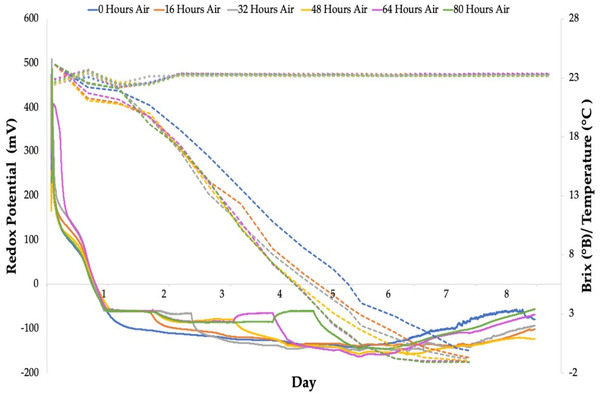


Figure 2. A composite figure of redox curves (solid line) and °Brix curves (dashed line) across six ferments subject to oxygenation for various times and amounts throughout fermentation demonstrating the relationship between fermentation kinetics and redox status. Composite temperature data (dotted line) is also presented.

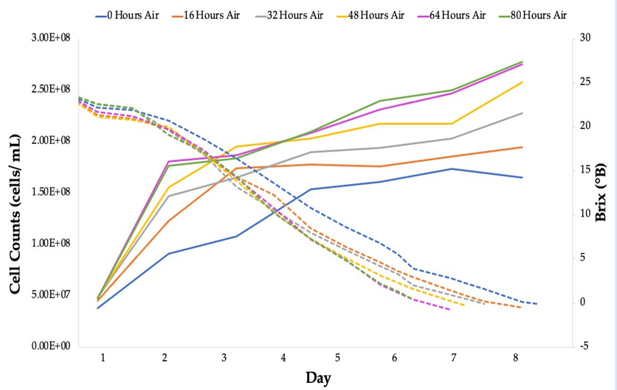


Figure 3. A composite figure of cell counts (solid line) and °Brix curves (dotted line) depicting the corresponding cell densities in relationship to fermentation kinetics and redox status.

Sample	Acetic Acid (g/L)
0 Hours Air	0.625
16 Hours Air	0.439
32 Hours Air	0.438
28 Hours Air	0.477
64 Hours Air	0.499

Table 1. Results of preliminary organic acid analysis for acetic acid from samples taken at fermentation completion. Data was generated via HPLC.

CONCLUSIONS

This study investigated how oxygen introduction, at various times and amounts during fermentation, effects redox status and how this is linked to overall fermentation outcomes. Differences in fermentation outcomes were assessed using redox curves, °Brix curves, cell densities and organic acid analysis. Our data, with other results not show here, demonstrate that the length of redox control correlates with fermentation completion times. When compared to the uncontrolled ferment, the ferments under the longest redox control demonstrated a 20% acceleration in fermentation completion. In addition, the faster fermentation kinetics correlated with higher cell densities. Lastly, preliminary organic acid analysis demonstrated a change in final acetic acid levels when redox was controlled.

This work offers insight into several potential industry benefits associated with redox control. Increased fermentation kinetics and increased cell densities promote both faster finishing times and more robust fermentations. This could increase the tank turnover rate during harvest and alleviate the logistical challenges of tank space. Less acetic acid accumulation in redox controlled ferments demonstrates that redox control has the potential the reduce volatile acidity or VA character in finished wines. Finally, while not directly tested here, redox control has the potential to reduce hydrogen sulfide formation[4]. This is of particular interest because it would not only reduce the need for copper fining, but also reduce costs associated with product loss due to faulty reductive character in finished wines.

As this work is ongoing, future research aims to:

- quantify the amount of oxygen required (i.e., target redox set point) in order to achieve desired fermentation outcomes
- characterize changes in wine chemistry (H_2S, organic acids, amino acids, etc.) under redox control.
- investigate redox control under production conditions (commercial scale & grape juice medium)
- perform a sensory evaluation to better understand the organoleptic effects of redox control.

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