

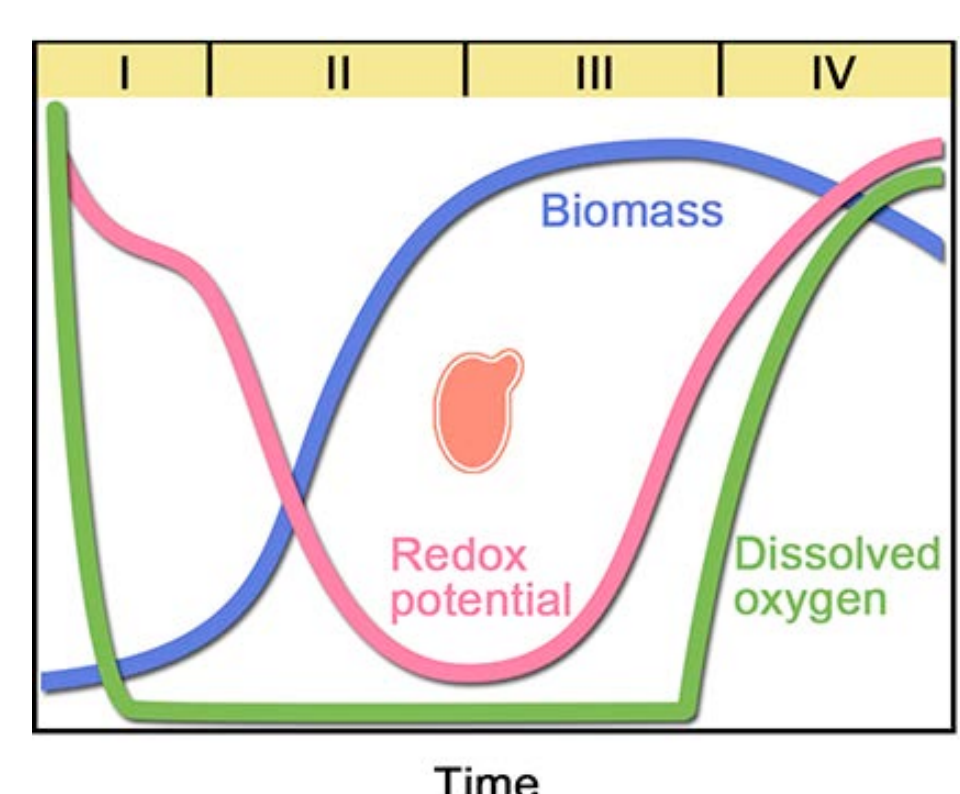
Monitoring site-specific fermentation outcomes via Oxidation Reduction Potential (ORP) and UV-Vis spectroscopy to characterize “hidden” parameters of Pinot noir wine fermentations

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Introduction

Real time process metrics are standard for the majority of fermentation-based industries, but have not been widely adopted by the wine industry. In this study, replicate fermentations were conducted with temperature as the main process parameter and assessed via in-line Oxidation Reduction Potential (ORP) probes and at-line profiling of phenolics compounds by UV-Vis spectroscopy. The California and Oregon vineyards used in this study, displayed consistent vinification outcomes over five vintages and are representative of sites producing faster and slower fermenting musts. The selected sites have been previously characterized by fermentation kinetics, elemental profile, phenolics and sensory analysis. ORP probes were integrated into individual fermentors to record how ORP changed throughout the fermentation process. The ORP profiles generally followed expected trends with deviations revealing previously undetectable process differences between sites and replicates. Site-specific differences were also observed in the phenolic and anthocyanin extraction over the course of fermentation.

Elemental composition was also analyzed for each vineyard, revealing distinctive profiles that correlated with the fermentation kinetics and may influence the redox status of these wines. The rapid ORP responses observed related to winemaking decisions and yeast activity suggest ORP is a useful process parameter that should be tracked in addition to Brix, temperature, and phenolics extraction for monitoring wine fermentations. This work demonstrates the feasibility and value for utilizing ORP probes in a production setting.



Typical profiles for Dissolved Oxygen and Oxidation Reduction Potential (ORP) during Anaerobic fermentation with yeast. (Liu, et al., Biotechnology Advances, 2013)

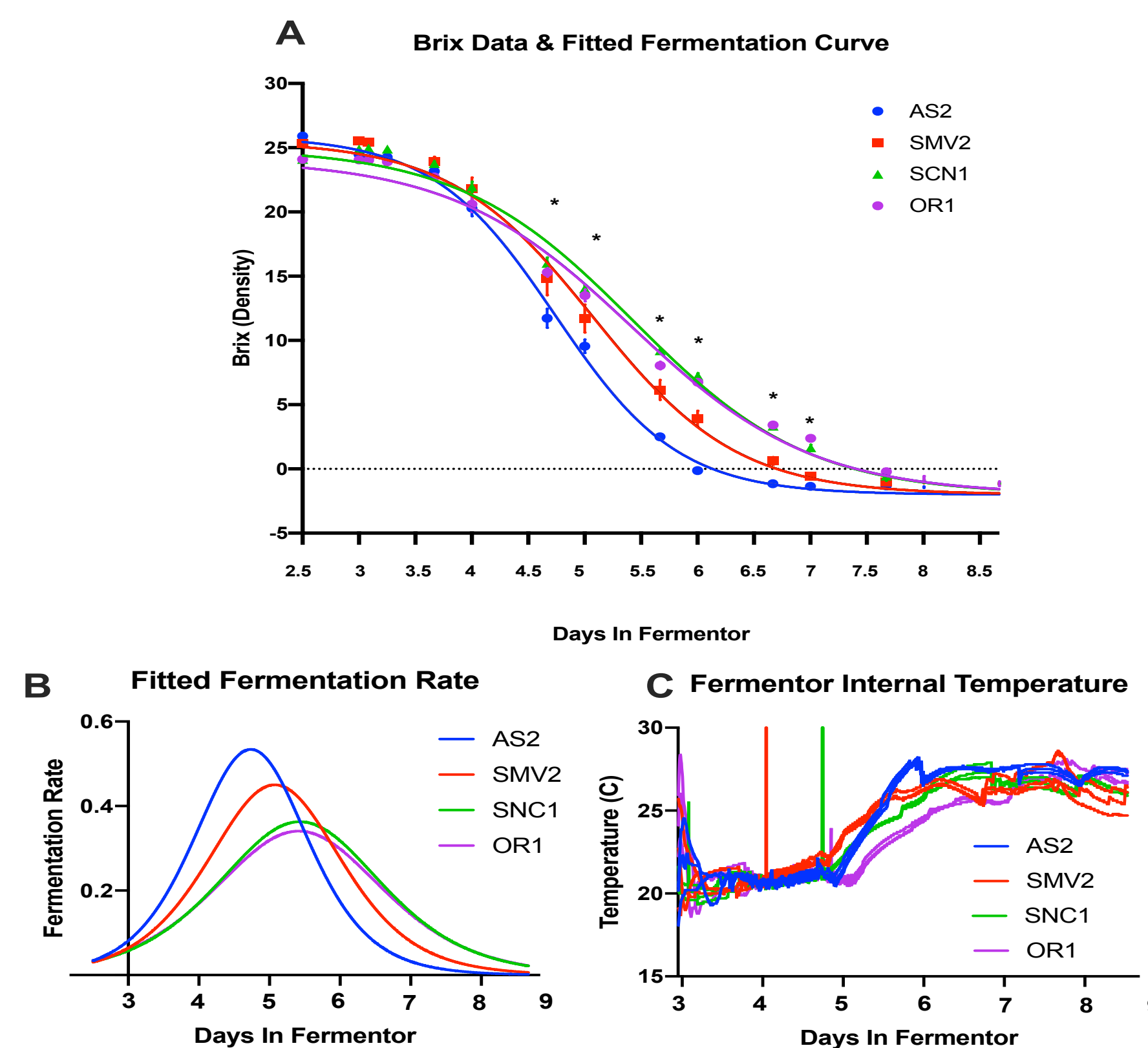


Materials & Methods

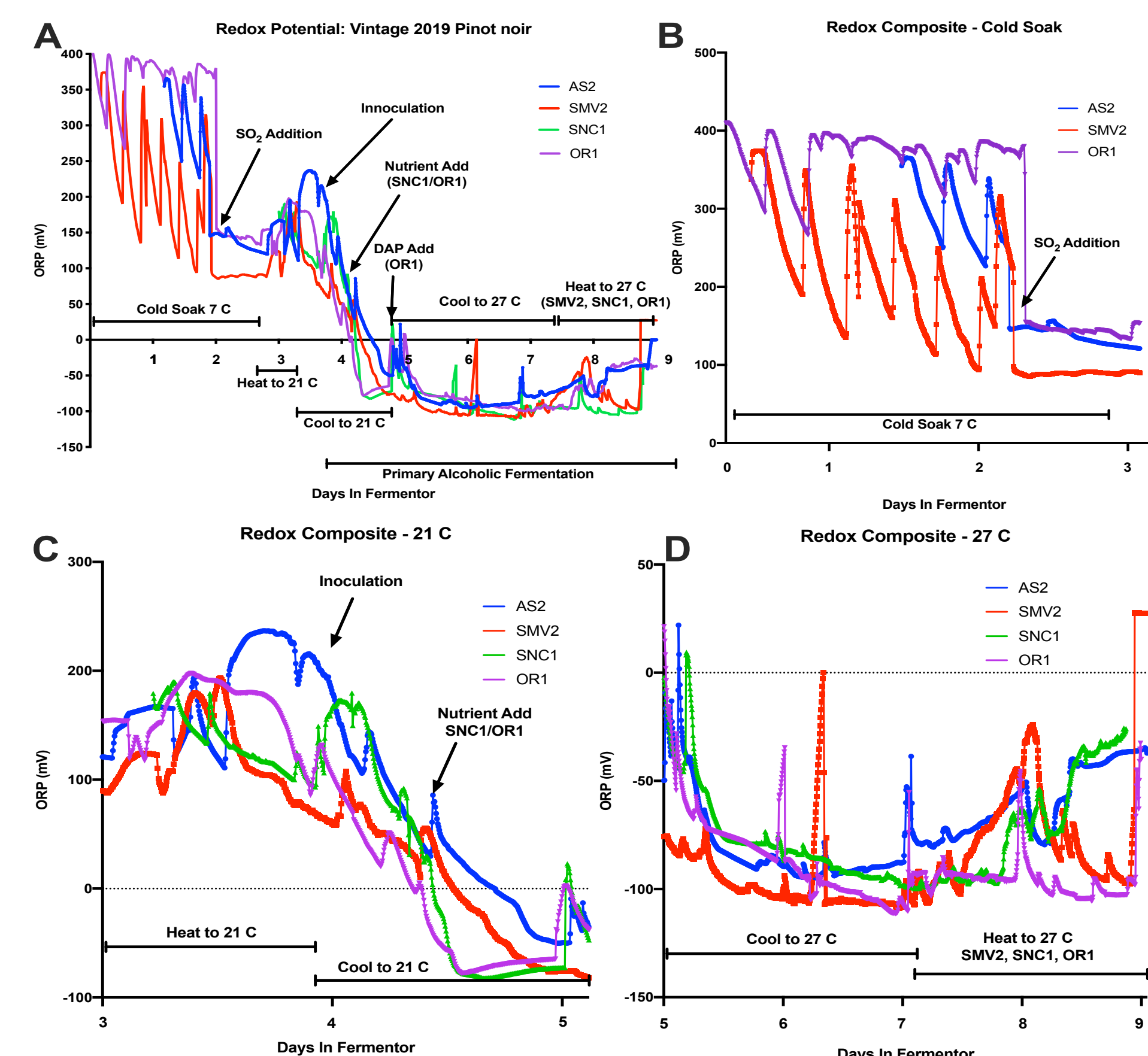
Pinot noir grapes were harvested and process at the UC Davis Pilot Winery. Fermentations were conducted with Hamilton ORP probes in 200 L “TJ Fermentors”. Triplicate lots were inoculated with RC212 (Lallemand) and fermented under similar conditions to minimize variability. Brix was sampled twice daily using a Anton Parr DMA 35 after a manual pump-over. Fermentation was controlled via temperature and automatic mixing. Phenolics and anthocyanins were sampled and tested using UV Spectroscopy (Wine X-Ray). Elements were analyzed using Agilent inductively coupled plasma mass spectrometry (ICP-MS). Wine Chemistry was assessed using the Thermo Scientific Gallery Analyzer. Alcohol was assessed with the Anton Parr Alcoholizer.

Fermentation & ORP

These sets of fermentations fell into two groups with “faster” and “slower” kinetics indicative of each specific vineyard site. The speed of the fermentations can be visualized by the rate and temperature increases. These differences are robust and have stayed consistent over 5 year vinifying these sites.

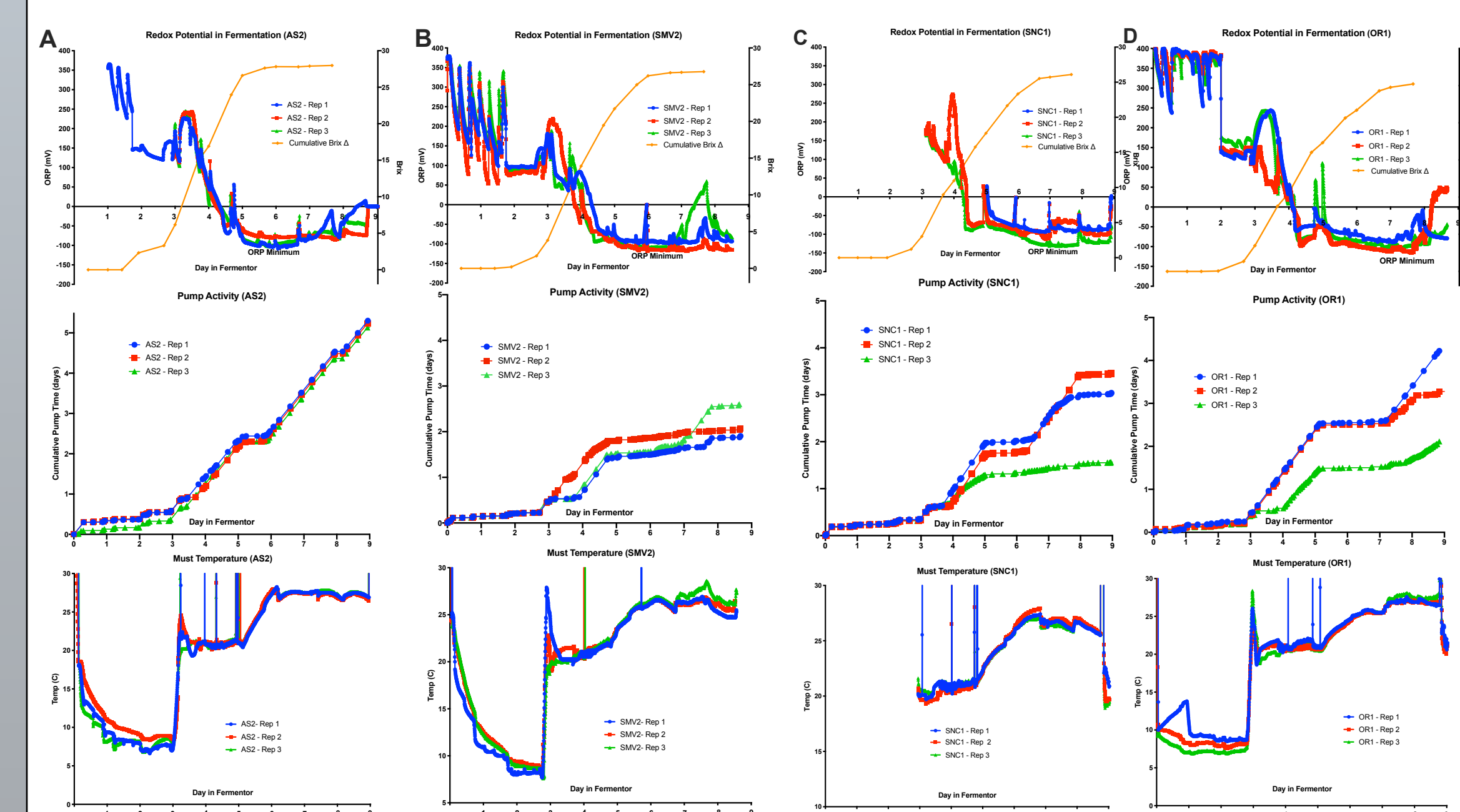


Generally, the mean composite ORP profiles followed similar general trends, because the process control strategy (temperature) was kept consistent across fermentations. Each phase of fermentation is shown separately with important process decisions annotated. Careful observation of the data shows how winemaking decisions can influence the ORP. The ORP profile appears to be a function of yeast activity and temperature during fermentation.

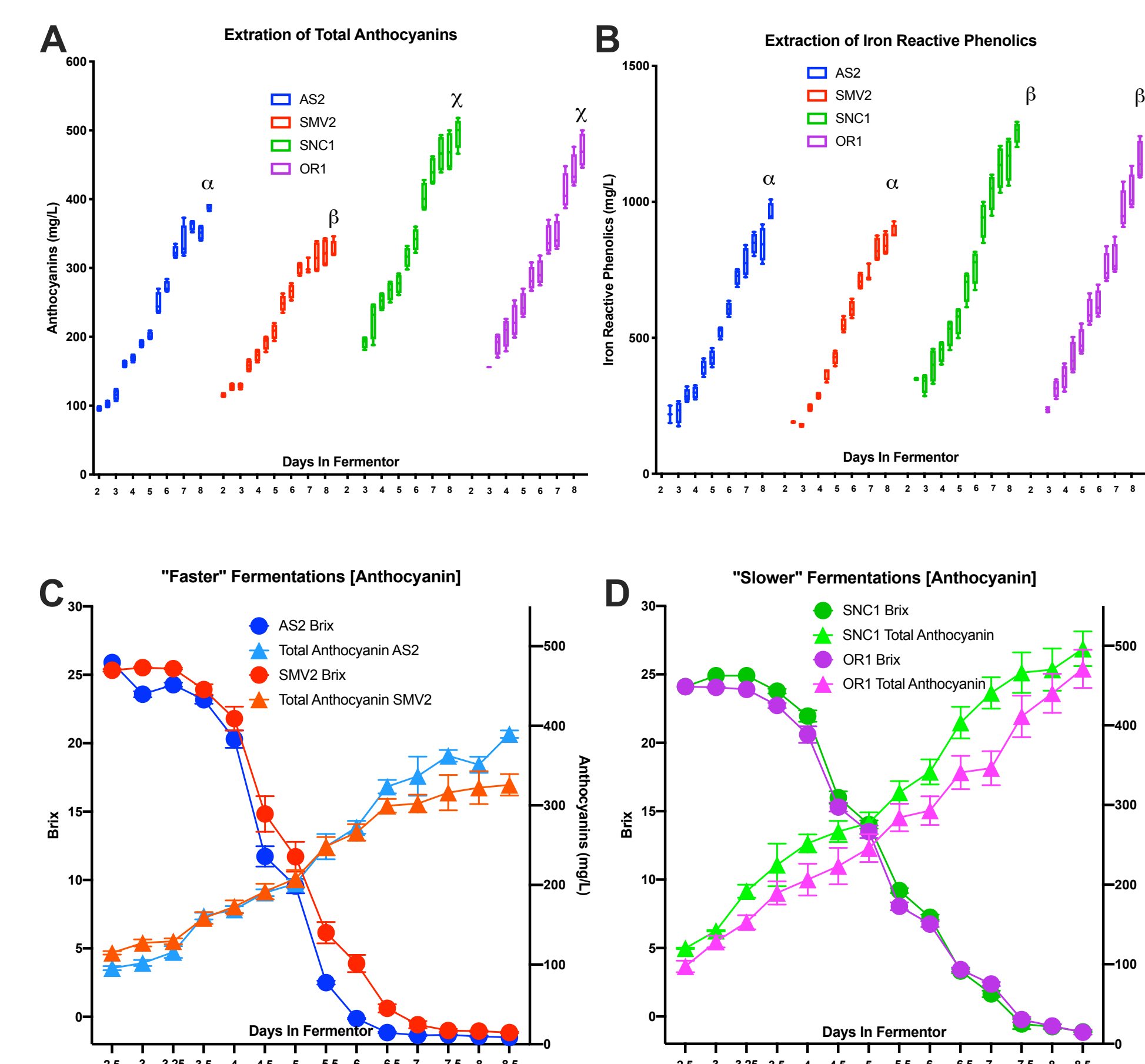


Temperature & Extraction

The mean ORP profiles show similar trends, but the individual ORP profiles for each replicate display distinct deviations during fermentation as a result of temperature and mixing. Pump activity introduces air, while yeast metabolism consumes it (dropping the ORP). Placing an ORP probe in each tank provides winemakers real-time insight into the dynamics of fermentation and provides a record for how process decisions influenced the chemical environment and yeast populations.



In parallel with ORP, the extraction of color compounds was assessed throughout the course of fermentation. The “slower” vineyard sites displayed higher levels of extraction of polyphenols and anthocyanins relative to the “slower” sites. There appears to be a geographic (latitude) correlation with color extraction. The kinetics of fermentation appear to be independent of the extraction in this experimental setup.



Elemental Composition & Wine Chemistry

Elemental composition is reflective of the soil type and farming practices. Profiling the elemental composition of the vineyards showed a clear segregation of the “faster” and “slower” sites. The ratio of Mn:Fe was particularly associated with fermentation kinetics over 5 vintages (data not shown).

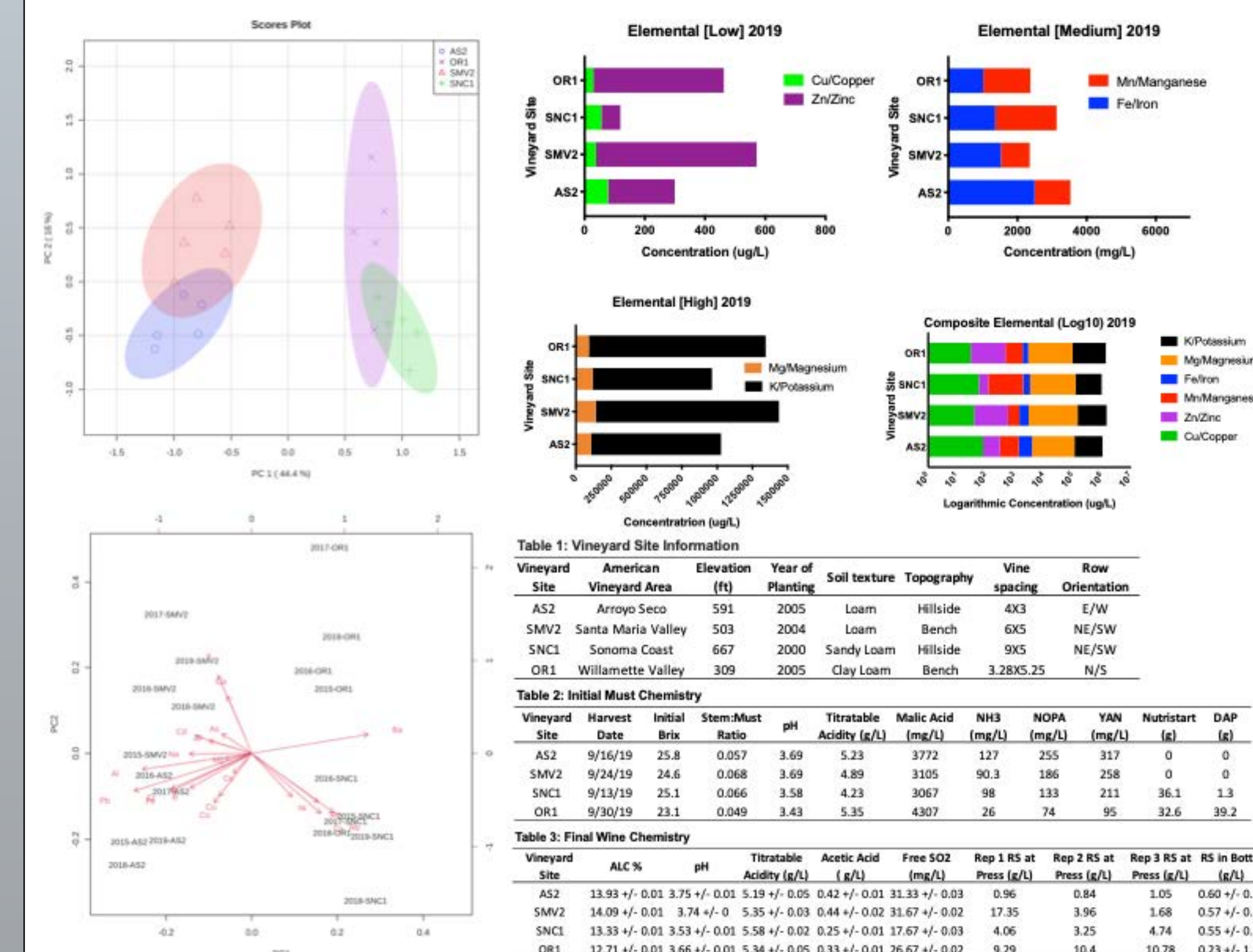


Table 1: Vineyard Site Information

| Vineyard Site | American Area | Elevation (ft) | Year of Planting | Soil texture | Topography | Vine spacing | Row Orientation |
|---------------|--------------------|----------------|------------------|--------------|------------|--------------|-----------------|
| AS2 | Arroyo Seco | 591 | 2005 | Loam | Hillside | 4x3 | E/W |
| SMV2 | Santa Maria Valley | 503 | 2004 | Loam | Bench | 6x5 | NE/SW |
| SNC1 | Sonoma Coast | 667 | 2000 | Sandy Loam | Hillside | 9x5 | NE/SW |
| OR1 | Willamette Valley | 309 | 2005 | Clay Loam | Bench | 3.28x5.25 | N/S |

Table 2: Initial Must Chemistry

| Vineyard Site | Harvest Date | Brix | Stem-Moist Ratio | pH | Titratable Acidity (g/L) | Malic Acid (mg/L) | NH3 (mg/L) | NOPA (mg/L) | YAN (mg/L) | Nutrient (g) | DAP (g) |
|---------------|--------------|------|------------------|------|--------------------------|-------------------|------------|-------------|------------|--------------|---------|
| AS2 | 9/10/19 | 25.8 | 0.057 | 3.09 | 5.23 | 3772 | 127 | 255 | 317 | 0 | 0 |
| SMV2 | 9/24/19 | 24.6 | 0.048 | 3.69 | 4.89 | 3205 | 90.3 | 186 | 258 | 0 | 0 |
| SNC1 | 8/13/19 | 25.1 | 0.066 | 3.58 | 4.23 | 3067 | 98 | 133 | 211 | 36.1 | 1.3 |
| OR1 | 9/30/19 | 23.1 | 0.049 | 3.43 | 5.35 | 4307 | 26 | 74 | 95 | 32.6 | 39.2 |

Table 3: Final Wine Chemistry

| Vineyard Site | Alc % | pH | Titratable Acidity (g/L) | Acetic Acid (mg/L) | Free SO2 (mg/L) | Res 1 RS at Press (g/L) | Res 2 RS at Press (g/L) | Res 3 RS at RS in Bottle (g/L) |
|---------------|----------------|---------------|--------------------------|--------------------|-----------------|-------------------------|-------------------------|--------------------------------|
| AS2 | 13.93 +/- 0.01 | 3.75 +/- 0.01 | 5.19 +/- 0.05 | 0.42 +/- 0.01 | 31.33 +/- 0.03 | 0.96 | 0.84 | 1.05 |
| SMV2 | 14.09 +/- 0.01 | 3.74 +/- 0.01 | 5.35 +/- 0.01 | 0.44 +/- 0.02 | 31.47 +/- 0.02 | 17.95 | 3.96 | 1.68 |
| SNC1 | 13.33 +/- 0.01 | 3.53 +/- 0.01 | 5.58 +/- 0.02 | 0.25 +/- 0.01 | 17.47 +/- 0.03 | 4.06 | 3.25 | 4.74 |
| OR1 | 12.71 +/- 0.01 | 3.66 +/- 0.01 | 5.34 +/- 0.05 | 0.93 +/- 0.01 | 26.47 +/- 0.02 | 9.29 | 10.4 | 10.78 |

Conclusion: This work highlights innovative ways for winemakers to follow the chemical and metabolic processes that would otherwise be “hidden”. ORP as a parameter is extremely sensitive to process changes, reflecting automatic and manual operations of fermentation conditions. Observable differences in the ORP between replicate fermentations and different sites appear to be strongly correlated with mixing/pump activity (air introduction). Extraction of color compounds is a function of site/origin that may be affected by fermentation kinetics and the redox conditions. Monitoring the phenolic extraction profile could provide another metric by which fermentation outcomes can be predicted or controlled by changing conditions in a directed manner. Analysis of the elemental composition revealed reproducible differences between vineyard sites; in particular the ratio of Fe:Mn correlates with fermentation kinetics. For future vintages we will continue to profile fermentations by tracking ORP, as well as to experiment with controlling the fermentative environment via an ORP setpoint.

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