GASES: CARBON DIOXIDE, ARGON, AND NITROGEN

Section 2.

Use of Gases in Wine Production

In the winery, inert gases are used for sparging, blanketing, as counter-pressure to move wine (usually from barrels), as well as to flush transfer lines and tanks prior to moving wine or juice. Sparging involves the introduction of a stream of very fine gas bubbles to help add or remove dissolved oxygen or CO_2.

The difference in partial pressures between the sparging gas and the dissolved gas (usually O_2) causes the latter to be swept to the wine's surface and into the headspace. Efficiency depends on a number of factors (Allen, 1991), including the following:

- physical properties of the gas
- bubble size and contact time
- temperature
- pressure and flow rate
- equipment design, e.g., porosity

Depending upon winemaker needs, spargers can be purchased with porosity ranging from 2 to 100 µm. In that oxygen solubility decreases with increases in temperature, both efficiency and effectiveness are improved at higher temperatures. Spargers that create a vortex just prior to injecting gas are recommended (Allen, 1991).

Blanketing partially-filled tanks attempts to maintain an inert gas layer above the wine/juice surface in the hope of minimizing wine-air contact. Some wineries utilize gas piping systems for tank blanketing, saving labor and minimizing safety dangers. There are several biological/chemical factors that mitigate the value of inert gassing of partially-filled tanks:

- In order to prevent the growth of aerobic microorganisms at the wine surface, O_2 concentrations must be reduced from the 20.9% found in air, to <0.5%. Although achievable, reduction of O_2 levels low enough to control biological growth for extended periods using inert gas blanketing is unlikely. Whereas nitrogen and CO_2 are often used to accomplish the goal, nitrogen is preferred because it has a very limited solubility (14 mg/L) relative to CO_2 (1,500 mg/L) in wine. Although "heavier" than either N_2 or air, the solubility of CO_2 in wine results in rapid dissipation of the protective layer.

- By comparison, wines stored in properly sealed barrels, with minimal ullage (headspace), develop a partial vacuum over time. If the vacuum is maintained, it helps to limit the growth of aerobic microorganisms.

- It is universally accepted that there is no better substitute for the protection of wine from O_2 than storage in completely-full containers.

Flushing tanks and transfer lines before wine transfer may also be accomplished with N_2, CO_2 (or "balanced mixtures" of the two), or argon. Gassing is best accomplished by introduction at the tanks' bottom draw. This ensures more complete displacement of oxygen out the top. Properly carried out, O_2 levels of less than 1% are achievable. Portable oxygen meters are useful for monitoring effectiveness.

If sparkling wine contains dissolved air or nitrogen, in addition to carbon dioxide, gushing can occur upon disgorging. For this reason, nitrogen sparging and excessive aeration of the cuvée is undesirable.

Gas Remuager

Use of automated air or inert gas-driven mixing systems, for cap management and mixing during red wine fermentation, is not uncommon. Some winemakers prefer to introduce gas by hand through a PVC wand at the bottom of a fermenting wine, although some systems require more complex installations. There are commercial systems available, such as Plus Air.

Hyper-reduction

Winemakers use the term *hyper-reduction* to refer to juice and wine processing techniques that attempt to avoid oxygen pick-up. Among these, the use of carbon dioxide as a “blanket” during pressing may help to minimize browning in unprotected juice. Lowering the oxidation-reduction (redox) potential of the juice also may help in preventing oxidative deterioration of labile aroma/flavor compounds, specifically thiols.

The debate regarding the importance of “green” vs. “brown” juice relates both to style and variety. The importance of fermenting green juice with limited oxidative degradation is, once again, gaining attention.

For example, the main volatile sulfur compounds important to Sauvignon blanc varietal character are easily oxidized. Therefore, protection from the impact of molecular oxygen at berry breakage aids in maximizing the box tree and passion fruit “notes” (derived from 3MHA, 3-mercaptohexyl acetate). This is a primary reason why some blanket at the press, and may also add ascorbic acid (vitamin C) to the juice.

Managing Oxygen during Bottling

Oxygen pick-up during bottling is an important concern influencing wine quality, stability, and longevity. Thus, the concentration of molecular oxygen should be measured before, and adjusted (using nitrogen or CO_2), as necessary, during the bottling run. Oxygen can be reliably measured using properly-calibrated oxygen meters.

Immediately prior to bottling start-up, hoses, filter housings, pumps, and the fill bowl should be flushed using nitrogen, carbon dioxide, or argon. Gasket integrity should be inspected, and connections should be tight prior to movement of wine. Bottling tanks should be intermittently blanketed with nitrogen or CO_2. Bottles should be completely free of particulate matter, and flushed with nitrogen just prior to filling. The following summarizes important concerns:

- Generally, pre-bottling, wines should have less than 0.5 mg/L oxygen. Increases of more than 0.2 mg/L dissolved oxygen during bottling indicate excessive pick-up.
- Oxygen pick-up may result from ineffective seals (lines, pumps, etc.), tank headspace, or low pressure in nitrogen canisters used for bottle flushing.
- Loss of free sulfur dioxide in wine is proportional to the dissolved oxygen content.

- Producers not using vacuum fillers, corkers, or bottle gas flushing can have up to 5 mL of air in the headspace of their bottled wine (750 mL), amounting to approximately 1 mL (1.4 mg) of oxygen.
- As a rule-of-thumb, 4 mg of sulfur dioxide is needed to neutralize the effects of 1 mg of oxygen, so an additional 5-6 mg of free sulfur dioxide is needed to reduce molecular oxygen in the headspace.

Monitoring oxygen in wine during any stage of processing, including bottling, is relatively easy. Several portable, hand-held meters with probes are available for measuring atmospheric and dissolved oxygen in wine. Depending upon bottling line speed, dissolved oxygen, as well as headspace vacuum and fill levels, should be monitored at thirty-minute intervals.

Practical Summary of Winemaking Issues

- Carbon dioxide, nitrogen, and argon are the three gases used most frequently in the winery.
- Each can be used to remove oxygen from solution.
- The three gases have different solubilities in wine, and other characteristics, that determine which gas should be used under which circumstances.

Study Questions

1. What are the factors that influence carbon dioxide solubility in wine?

2. What are the factors that influence the sensory perception of carbon dioxide?

3. What Virginia varietal wines would you suggest could benefit from having carbon dioxide at bottling? What levels and why?

4. Calculate the total carbon dioxide emission from 35 tons of Virginia Merlot grapes.

5. Why should the wine industry be concerned about the carbon dioxide produced during fermentation? What steps could be taken to limit emissions?

6. Explain how nitrogen can remove carbon dioxide from solution.

7. Storing wines in partial containers is frequently not viable, even when displacement gases are used. Why?

8. Sparkling wine cuvées which contain soluble nitrogen can cause gushing in the finished product. Why?

9. Explain the principle of hyper-reduction.

10. Many Virginia wineries bottle wines without the use of a vacuum corker. What are the detriments of such an activity? How can the potential problems be abated?

References

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