The Birth of Precision Bottling

Audit of bottle oxygen variation in winery trials shows size of the challenge

By Clark Smith

Of all beverages, wine is the most varied. While one can classify beers into a handful of types, and spirits into 10 basic bar pours and a hundred cordials, wines cannot be lumped into any less than 1,000 significant varietal types and European appellations, plus any number of proprietary blends. There are more than 250,000 wine brands for sale in the U.S. market alone, and easily 1 million for sale somewhere in Europe.

Yet within this variation lies one prime directive: that a given specific label shall be consistent within itself. Wines do not exist to slack thirst, but to spark the intellect. Specific wines of any stripe are presupposed to be as consistent as movies, with every copy identical. Without this cardinal rule, the entire edifice of wine sales—*Wine Spectator* scores, Parker reviews, tech sheets, gold medals, flash sales, blogs, point-of-sale advertisements—collapses.

Sophisticated collectors have come to expect and tolerate the bottle-to-bottle variation that accompanies decades of aging, but the workaday wine world is founded on the assumption of product consistency. Like the public faith that sustains the dollar, the economy that pays your salary is firmly rooted in the unshakable belief that for any wine we choose to evaluate, its replicate bottles will behave likewise.

There is just one problem. It isn't true.

I am not talking about cork taint. That unhappy phenomenon, which first bloomed in the public consciousness in the late 1980s, is easily identified by an expert and exists in no more than one bottle per case under cork. Wineries took action, and this incidence has been further reduced by the growing prevalence of alternative closures. The media, for once, has embraced these new technologies and cooperated in educating consumers. This threat to the industry has been, in my estimation, artfully avoided.

Winemakers use NomaSense technology to measure oxygen pickup inside tanks, hoses, pumps and bottles (above).

That moldy compound TCA is no longer Public Enemy No. 1. A five-year average of the incidence of technical flaws leading to rejection at the London International Wine Challenge reveals that cork taints were found in 1.8% of wines submitted, comprising 27% of expulsions, with oxidation (27%) and reduction (26%) together comprising more than half of flawed wines, dual artifacts of winemakers' inability to manage oxygen. As we peel the quality onion, total package oxygen (TPO) management is now in the spotlight.

A new tool

Though it has grown into the second largest supplier of wine closures behind Portuguese natural cork firm Amorim, when Nomacorc appeared on the scene in 1999, its stated objective was to eliminate bottle variation. It turns out to be utterly impractical to attempt this through the simple expedient of a reliable co-extruded cork alternative. Without a consistent closure, to be sure, even the most consistent bottling will turn out inconsistent wines.

But, growing evidence suggests that no matter how good the closure, bottling equipment and procedures have turned out highly inconsistent TPO levels. Wines in the same shipping case, particularly fragile white wines, were exhibiting substantial sensory quality variation.

Nomacorc's response to this challenge was to develop an optical sensor system capable of reading oxygen concentration through glass. Christened NomaSense, this system allowed winemakers for the first time to study oxygen pickup inside fully sealed tanks, hoses, pumps and bottles.

Much of the new instrumentation's reason for being involved bottling line auditing procedures that were simple, non-destructive and non-invasive, enabling differentiation on a scale never before contemplated, such as assessment of individual filler valves. Measurement

Highlights

- A survey of variation in total package oxygen (TPO) among 17 wineries reveals startling challenges for wineries large and small.
- Wineries commonly exhibit a U-shaped curve, with high dissolved oxygen at the beginning and end of the run, which is not alleviated by standard inerting practices.
- The highest contributor to TPO is the headspace oxygen on screwcap lines.

of TPO for each bottle immediately after filling was calculated by combining O_2 in the headspace (HSO) plus oxygen dissolved in the wine (DO). Headspace and filled wine volumes were used to compute TPO for a specific bottle as opposed to its adjacent fellows. This level of granularity had never before been imagined.

Formation of the Collaborative Council

In 2012, Nomacorc organized a panel of 40 industry experts including production winemakers, academic enologists, quality-control specialists and winery research team leaders to oversee collaborative studies that might shed light on the sources and extent of TPO variation. The Wine Science Forum (WSF) advisory council now meets regularly to coordinate research, discuss results and organize seminars to share the group's work and solicit input from wine producers at large.

Initial findings presented at the Conference on Oxygen and Wine Quality in March 2013 were not encouraging. TPO was seen to vary typically by 1 mg/L within the spouts from a standard 30-spout filler. Research was presented to suggest that such variability caused differences in freshness, fruit intensity and other key quality determinants in whites. Even in reds, where oxygen pickup can be beneficial, sensory effects also varied bottle to bottle.

On the bright side, the NomaSense apparatus proved itself a valid scientific instrument, and the methodology of calculating TPO entered the mainstream of academic enological parlance.

Getting serious

Subsequent to the conference, the WSF advisory council determined that a more wide-reaching study of bottling variation should be undertaken that could account for variability in practices among producers in order to gain a sense of the overall situation in the industry.

The team formed to conduct the survey was led by Dr. Hend Letaief, newly recruited to California State University, Fresno, after cutting her teeth under leaders in the phenolics research field at the University of Montpelier. She was assisted by Ashley Heisey, one of Napa's most clued-in and meticulous winemakers. Added to this team were Pauline Martinaggi and Bertille Goyard, French interns on loan from ESA Angers School.

Seventeen California wineries of varying size were chosen for an in-depth audit of a single day's bottling. Bottlings of nine red wines and eight white wines were studied. Wineries varied from 22 to 550 bottles per minute, employing between eight and 100 filler heads, and bottled volume ran from 525 gallons to 27,000 gallons. Eight runs employed natural corks, five used Nomacorc synthetic closures, one inserted agglomerated cork alternatives, and four were sealed with screwcap closures.

Most wineries reported use of inert gas before and after the process; liquid nitrogen drops and wine recirculation for priming also were evaluated.

For each winery, dissolved oxygen (DO) was monitored throughout the day in the bottling tank bottom valve and at the filler at one, 50, 150, 300 and 500 bottles into the run as well as at the end. Individual bottles from up to 16 heads were assessed for HSO and DO at the beginning, middle and end of the run.

Triplicate samples enabled estimation of error bars. As you will soon see, this beautiful study allows us to discriminate between measurement precision and actual sources of variability; between the noise of our instruments and the signals

that help us fix the right problems, such as valve performance, vacuum variability, time of sampling during the run and closure selection.

Sneak preview of results

Pending formal publication of the study's findings, I offer here some extracted juicy nuggets in advance. Let's begin by examining a typical "U-shaped" bottling curve (see Dissolved Oxygen in Wine Throughout Bottling Run).

It is worth noting that despite the 500-bottle descent to the running DO level, this winery claimed to inert the line before commencing, maintain an inert gas headspace in the sending tank and prime the line with recirculated wine.

Well, it didn't work. I bet your winery thinks it's doing all the same things. The Wine Science Forum study reveals a world divided into wineries that actually achieve a flat curve and others that only imagine they surely must. It is extraordinary to note here that it took all of 500 bottles to get down to a normal running DO. Many wineries recirculate a few gallons and call it good. Measuring would be better. Inerting the filler bowl might also have helped.

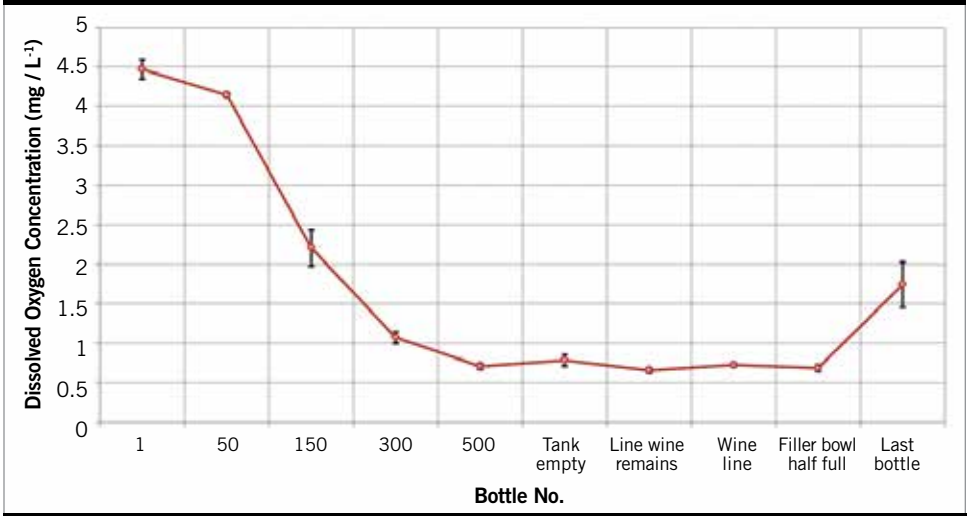
Once the run moves beyond initial oxygen incursion, DO tends to run steady throughout the run if interruptions do not occur such as malfunctions or lunch. The base DO rate is primarily determined by oxygen exposure during recent treatments (racking, filtration) and the oxygen appetite of the wine.

Failure to maintain inert gas headspace in the sending tank will cause the last bit of wine to rise in DO, augmented by pumping of air bubbles and other job end phenomena.

Most everything you need to know to eliminate TPO bottle variation is hidden in the graph TPO Partitioning at California Wineries (see page 60).

Let's walk through the high points of the graph. The gray bit at the bottom of each winery's bar is the average DO in the

U-Curve of Dissolved Oxygen in Wine Throughout Bottling Run



Initial TPO can require a surprisingly long time to normalize.

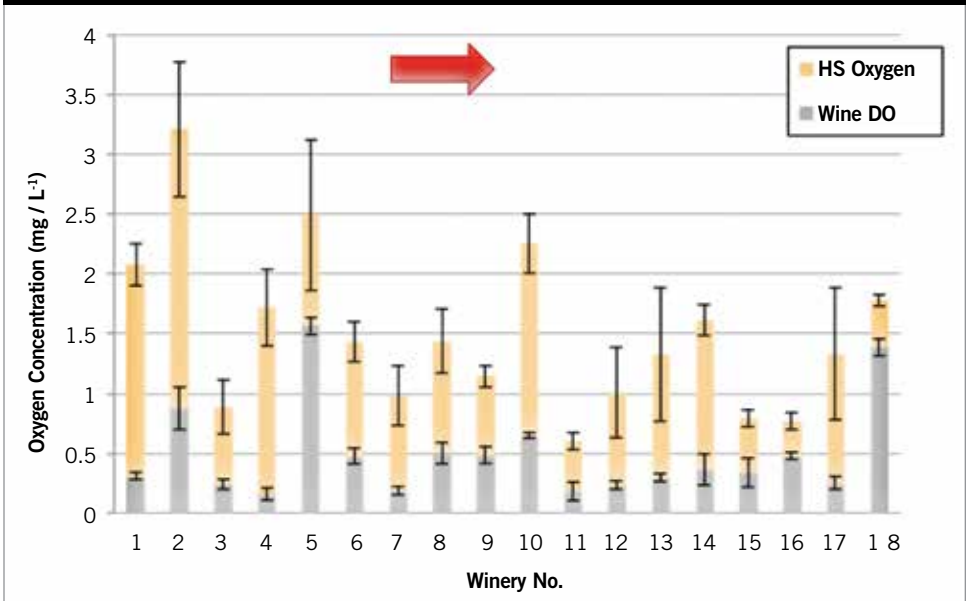
body of the wine, and the yellow above it reports the headspace. The two together give you the TPO.

The differences between wineries are alarming. Good wineries can manage TPO less than 1 ppm. That looks like the goal. The other wineries are getting 2-3 ppm. We have already discussed the sources of high initial DO.

Now check out those errors bars. The first thing you notice is the very high variability in HSO. Wine DO is practically constant. That means that we can stop worrying about the splash patterns of individual spouts. Far more important are causes of HSO variability, which include bottle-gassing equipment, vacuum at the filler and multi-head corker. There is a lot of variability in HSO error bars, so some wineries do get it right.

Wineries 5 and 10 illustrate the special problems of small wineries, bottling small lots of red wine through small fillers. Winery 5 had a lot of initial DO and a moderate but highly variable headspace oxygen. Winery 10 did much better on the wine DO and the variability of DO, but it had a very high headspace oxygen when one considers that an inserted closure was used (leaving a tiny headspace), so the lack of variability was probably simply a lack of any vacuum at all. If these were big, young reds with high oxygen appetites, there would likely be little cause for concern until these wineries went to bottle their Sauvignon Blancs on the same systems.

TPO Partitioning Measured by 18 Trials at California Wineries



Wineries differ widely in levels and variability of TPO.

Scanning for the remaining high HSO wines, we highlight wineries 2, 4, 14 and 17, which include some very high-volume, highly professional facilities. The common thread? These are the four screwcap closures.

Particularly telling is the comparison of wineries 14 and 15—actually the same winery bottling the same wine with screwcap in the morning (14) and synthetic closures in the afternoon (15). Despite the use of liquid nitrogen drip post-filling to inert the headspace of the screwcaps only, we see a huge increase in the TPO due to headspace O_2.

This highly professional configuration is actually the exception. In general screwcap bottlings displayed both high HSO levels and variability.

These data do not challenge the widely held belief that when properly applied and spared from physical damage, screwcap closures (at least the ones based on tin liners) can provide a nearly hermetic seal with a consistent and very low oxygen-transmission rate. The tradeoff with today's technology is that they leave a very large headspace that cannot be evacuated with vacuum. In addition, half measures such as liquid nitrogen drops to minimize HSO may result in very high product variability in sensitive whites.

The bottom line

1) Set yourself up for measuring DO pickup in your finishing process prior to bottling. Good auditing equipment is available and expertise is valuable. You can also consider hiring a consultant to help you get your act together by auditing your line, reconfiguring your procedures, selecting measuring equipment and training your team.

2) Eliminate the U-shaped curve by back-gassing your sending tank with a pancake regulator at high flow/low psi. Inert the filler bowl and other sources of oxygen. Recirculate adequate quantities of wine.

3) Inert gas and oxygen are invisible. It's really easy to fool yourself by enacting procedures in name only. Liquid nitrogen drips and other measures may look good on paper, but make sure they work.

4) Measure your wine's oxygen appetite, and suit it to the aging trajectory you require and the closure you choose.

The study's full findings will be revealed in early 2015. Visit winescienceforum.com for more information. W&V

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