The most pressing technical issue for the wine industry today is closure quality control. Accordingly, the 28th annual conference of the American Society of Enology and Viticulture, Eastern Section, titled “Put a Cork In It?”, which focused on wine closures from all angles, was relevant to producers anywhere, and drew some participants from the West Coast as well as from across the East.

The conference took place in Corning, in the Finger Lakes district of New York, in July 2003. The coordinator for the conference theme was Roland Riesen, enologist at Youngstown State University in Ohio and a Director of ASEV/ES. He explained that the overwhelming range of types of closures and variations within each type required a thorough scientific overview. "Too much anecdotal evidence in the industry is taken as fact, without conducting thorough and scientifically significant trials, or knowing how to do them. Therefore, we had presentations by scientists with hard data. Presentations should go beyond touting proprietary products. I was interested in facts." The conference sought to examine closures from all angles; through technical studies, consumer studies, taste tests, winery experience and cost analysis.

Speakers included academic researchers, winemakers and suppliers. Gaining valuable perspective outside the wine industry, Riesen invited George Crochiere, a consultant in the beverage packaging industry with research experience at W.R. Grace, to share the methods and analyses used by other beverage industries in approaching closure quality control.

Quality Control Improvements in Detecting and Eliminating TCA and Related Taint

"Progress against Cork Taint: Origins of TCA in Natural Corks" was presented by Peter Weber, President, Cork Quality Council. Inspection, identifying bad corks and sending them back is the quality control process of the CQC. Weber explained how the evolution of better inspection to more precise levels had greatly increased quality control and lowered the rate of cork taint to the CQC winery members.

Weber noted that studies have shown wines perceived to be "corky" to mostly have TCA (formally known as 2-4-6 Trichloroanisole) as the culprit, with minor taint rates due to 1-octen 3-one, guaiacol and geosimin. The origins of TCA are mostly in the cork forests; aspergillus, penicillium and other opportunistic molds then react with chlorine in boiling water. "The first step is getting the cork bales off the forest floor." However, Weber noted that TCA can originate in chlorophenols, in tap water or winery drains as well as in corks.

The Cork Quality Council works with ETS Labs in California and has developed a protocol for testing and analyzing corks, to a sensitivity of one part per trillion. Since the majority of cork TCA is not released (the average is between 0.05% and two percent), they focused on measuring "releasable" TCA, defined as the TCA equilibrium in a cork soak. Weber noted that some firms have touted methods of treating corks to remove existing TCA; "I think it's very difficult to eliminate TCA once it gets in the cork; better to keep it out in the first place."

To determine the behavior of releasable TCA in bottled wine, CQC took individually analyzed corks for TCA levels, dried and coated them and inserted them in wine, then did a study over 14 months. Fifteen percent of releasable TCA was transferred after two months; 50% after 14 months. White zinfandel was used in the study; higher alcohol wines could have transferred more.

As a result, Cork Quality Council introduced a new QC protocol, purchasing solid phase micro-extraction (SPME) equipment, contracting to ETS to conduct analyses, using composite soaks on incoming bales, and sampling 650 on lots of 500,000 (an increase of over tenfold from their former method). Currently the protocol provides no false positives, and average TCA scores on incoming bales have been reduced by 68% by identifying marginal suppliers, and focusing on reliable ones.

"The invisible hand [of the marketplace] is at work; we don't know what they're doing to improve cork quality at the source, but they have a strong incentive when bad bales are shipped back to them at their expense." CQC has noticed the number of "high risk bales" for incoming shipments has dropped 85% since Sept. 2000. With better TCA level detection, selection of suppliers of good quality corks follows accordingly; economic pressure brings better QC at source; and also gives good feedback to new techniques being used at the source through testing results.

While the Cork Quality Council analysis improvement is encouraging, it is also sobering to reflect that failed bales returned to the suppliers are then recycled in the industry by being sold lower down the supply chain, in cork material closures of a cheaper grade. For closure quality control, cheap can be expensive. Accordingly, it's never been more imperative than in the closure business that the "buyer beware."

It's also important to understand that there are several compounds responsible for musty aromas/ tastes besides TCA, Riesen points out. "Equally important is the understanding of where TCA and the other compounds are created (including environmental), and how they are transferred into wine. Wine which has never seen a cork can be corky!" Cases have been reported of cellars tainted with TCA, which did not originate in corks, which then contaminated all wine processed in these cellars.

Evaluating Natural and Alternative Closures

"Natural and Alternative Closures: Winemaker's Concerns" was presented by Ken Fugelsang, Fresno State University. He opened by recommending that before moving to alternative closures, winemakers should examine some considerations: expected shelf life (most alternatives today are good for less than one year); product line segmentation and production levels; age and condition of bottling lines; and aesthetics; how will customers respond?

Current cork-type options in the market circa 7/03 included natural cork cylinders, agglomerates and "tech" corks, and synthetic "plastics." Fugelsang notes that natural cork

has exceptional compression and recoil that nothing else has, with a density of 40 x 106/cm3, is air filled, with low specific gravity.

Agglomerates are inexpensive alternatives, designed for short-term use because an effective seal deteriorates after 12 months, says Fugelsang. They use granulated cork which has been washed. Tech corks include synthetic materials in the mix to increase recoil and compression, and can have foodgrade binders. Agglomerates require twice as much force to insert, meaning bottling rates of up to 30% slower. For optimal expansion, Fugelsang notes they should be stored neck down prior to shipping.

Synthetics can either be of elastometric polymer synthesis, or extruded. There is a slower running time on bottling lines between agglomerates and natural corks, as well as a need to decrease the headspace vacuum. "Evidence suggests synthetics can hold CO2 better than other still wine closures, and can be stored better neck up."

A pre-bottling quality control should include physical measurements to ensure compatibility with bottling line, and for cork products, evaluation of sensory properties. Moisture content of corks is very important and should be between five and seven percent; above there is risk of mold, and below is risk of cracking and seeping. Corks can change moisture content in shipping long distances.

Fresno State did a comparison study of four commercial closures in 2001. Sauvignon blanc was bottled with four commercially available closures; two were synthetic, one "tech" and one a high-end natural. Six hundred bottles were bottled with each closure, aged one year neck down. The first sample was evaluated 50 days post-bottling; fill level, analytical and sensory tests made included free and total SO2.

The results revealed that total SO2 levels dropped steeply in the first four months. Natural and "tech" corks were very close, but there was a huge difference between two different synthetics. Free SO2 differences were more dramatic; both corks were in the middle, and the first synthetic closure outperformed all others.

Fugelsang recommends deciding your acceptable quality limit for defects in sensory evaluation; "The lower the reject limit, the more time-consuming and expensive the QC process. Microbiology and sensory are the main things to evaluate. Double sampling can be used for more accuracy."

In conclusion, Fugelsang noted that the winemaker has choices, there is no perfect closure; consider trade-offs and do a risk/benefit analysis. "In-house trials are imperative before changing your existing routine," such as the tolerance of the bottling line for corks of different compression levels. His recommendations are to deal only with established, reputable suppliers ("All parties must understand what the expectations are for the closures"), and setting up a winery in-house QC program for closures.

"Assessment of the Performance of Various Types of Wine Bottle Closures during Storage of White Wine-Results to 3 Years Post-Bottling" was presented by Leigh

Francis of the Australian Wine Research Institute in Adelaide. The study aims were to collect data on many variables on closure performance to determine the relative importance of each variable in closure quality.

A 1999 Semillon from Clare Valley was the only wine used. Closures evaluated included aluminum (screw cap), two natural corks, two "technical" corks, (Altec and Amorim), three extruded closures, and six molded synthetics. Wines were bottled in two runs of 300 bottles each on 5/26/99, plus one round of 800 bottles with the screw cap; bottling order was randomized to reduce impact of temperature and dissolved O2. Wine was stored in controlled temperature warehouse in stable humidity and case stacking order was randomized, with air space between stacks.

From six months on to 36 months, at regular intervals, measurements were taken for extraction energy and re-insertion, SO2 levels, visible browning, TCA levels, and a sensory evaluation. Francis noted that some synthetics were very difficult to extract; one corkscrew worm broke off in the plug. Over a year, some synthetics grew more difficult to extract, some agglomerates grew easier.

Free SO2 results revealed that the screwcap consistently retained the most free SO2, then all cork variants, then synthetics at the bottom (Altec had best results of cork types). At 24 months the closure types start to spread in their capacity to hold free SO2.

Browning results paralleled results for free SO2, with screwcaps and Altec the best. Visual results via slide at 28 months ranged from unchanged to clearly browned. Free SO2 at six months correlates well with levels at 30 months and browning color after 30 months and is therefore a good predictor of future performance for short-term trials.

Sensory data were obtained every six months to three years with a ten member panel. Individual fruit components were measured along with honey, toasty character and oxidized, glue-like and plasticy aromas, TCA and molds, reduced or flint/rubbery characters were also rated. Synthetics were highest in oxidized character with some honey/toasty character; the screwcap was highest in fresh fruit but also in f lint/rubber; natural corks had TCA (Altec consistent in each sample) with some honey/toast scores.

All synthetic corks had the biggest impact of flavor scalping (absorption of typical fruit aromatics/flavors), such as with reducing the kerosene volatile in some rieslings; the screwcap had the least.

Origins of Chloroanisoles in Wine

Ken Fugelsang of Fresno State returned as well to present "Chloroanisoles in Wine: Closure-Derived or Environmental?" He defined "Cork Taint" as a collection of microbially produced compounds loosely held together by descriptors of musty/earthy/ moldy. Causes range from mold and bacteria to algae. Sensory levels are very low. Taint has been reported in water, beer, fruit drinks and milk; as well as chocolate, dried fruits and other foods; packaging could contribute to its development.

Examining the precursors to chloroanisoles in the environment, Fugelsang pointed to bleaching agents in cork production (now largely replaced by peroxide) and other industrial cleaning agents with chlorine as a major component. Wood preserving agents, such as trichlorpheonol, can also be culprits. Cork-derived chloroanisoles tend to be random in nature rather than determined by the environment unless negatively influenced by same, and are not uniformly distributed in natural cork.

Wood can easily be a host for precursors to TCA; any packaging material (fabricated wood) like pallets, shipping containers, cardboard boxes, labels; even glass bottles are suspected of contributing to environmental TCA. Changes in temperature and relative humidity in transport can accelerate the problem.

"Never use chlorine or chlorine-containing agents in cleaning the winery!" admonished Fugelsang emphatically. Environmentally-derived TCA can be readily absorbed; uptake is rapid, within a day. Possible mediums for TCA contamination in the winery include tap water, transfer hoses, filter pads and fining agents, and polymeric tank liners which, combined with chlorine cleaners, can form TCA and contaminate the wine. A Fresno State study titled "TCA Distribution in Bottled Merlot: Closure- Derived Taint" examined 60 cases of California merlot from the '99 vintage. Suspected tainted corks were dissected and analyzed with the wine. The central part of the closures had 8.9 ng TCA, while the outside surface had seven ng, and the wine had six ng. The implication is that the longer a wine remains in contact with a TCA-contaminated cork, the higher the taint level becomes as TCA levels are equalized.

Study conclusions were that 70-80% of chloroanisoles taint is cork-derived and random, but environmental taint is a potential problem and can taint 100% of production. Prevention regimen involves carefully screening all wood-based winery supplies prior to use, eliminating all chlorine-based cleaners, setting up a QC protocol to screen incoming cork shipments prior to use, and working only with reputable cork suppliers who are willing to discuss their in-house QC including sampling and testing protocols. Fugelsang says the study results are not public yet, but will be published when ready.

In response to a question on pallets, Fugelsang is replacing wood pallets in his academic winery with polymeric plastic pallets which are expensive but durable; barrels wrapped in plastic should not be a problem unless stored that way for awhile; empty bottles stored in cardboard cases may pick up TCA precursors.

"How the Consumer Determines a Good Cork-Survey Results", was presented by Peter Weber of the Cork Quality Council. Weber notes that many closure surveys are skewed in the direction of the sponsors, and wanted a more objective evaluation for the industry. A recent survey showed that 70% of consumers rated previous closure experience as the most important factor for choosing wine closures.

A CQC member winery did a survey with three parts: listing criteria for judging cork quality, quality ratings by cork type, and the perceived benefits of natural cork. The

panelists were two groups of consumers and restaurant servers in Chicago and San Francisco.

The most important evaluation criterion was extraction characteristics (57%), then physical appearance (19%). Reliable composition and the sound of the cork popping were high priorities. Weber said that visually, consumers tend to prefer the chlorine wash corks for brighter color.

Grades A and B of cork quality had highest favorable ratings, longer corks had lower average ratings than shorter corks of the same type, possibly due to some who thought longer corks meant more difficult extraction.

The perceived benefits of natural corks included "emotional" benefits (part of tradition, romance and sophistication); "practical" benefits (allows for proper wine aging, natural cork is easy to re-seal) and "reassuring" benefits (quality cork gives early indication of quality wine, adds authenticity from imprint of name/logo matching label).

Trends in Future Closures

The final session of the regular program was "The Crystal Ball: Wine Bottle Closures in 2020," featuring a panel of speakers. Leigh Francis of the Australian Wine Research Institute began. "I think screw caps are desirable but we know there are marketing issues; good quality cork is best for aging wines. How much oxygen is appropriate for aging quality red wines is a question that should be researched. Flavor scalping will continue to be an issue with synthetics," he warns.

Francis announced a new breakthrough in prevention of TCA taint through Vinpac, the Australian packaging company; a coating polymer has been developed as an impermeable seal against any TCA which may exist in the cork; "that will be a very interesting development to follow which could influence choices in the future." According to the nanotechnology branch of the Department of Science and Engineering at Flinders University in Australia, two patents have been issued for this new technology and a new product is awaiting release. A Vinpac spokesperson acknowledges the new product is being developed but declines any comment until they are ready for commercial trials. *[Note: The new technology has since been released to the market by Vinpac under the brand name proCORK]*.

George Crochiere of Crochiere & Associates also returned. He notes that TCA is being reduced more, but natural corks may generate more complaints from consumers who think synthetics are more reliable. "Synthetics are here to stay," being good for short shelf life wines. Screw caps will still be here, and he believes the technology spillover from beer and soft drink industries will improve barriers, and oxygen scavengers in closures will become common, even controlled oxygen ingress for precise 'aging.'" You will have plastic caps and plastic [wine] bottles within 20 years," Cochiere predicts. He also predicts new coolers and flavored wines. "The new generation of drinkers accepts plastics as normal; they'll view glass and corks as relics of the past."

Crochiere sees the closure issues for the wine industry to focus on as cork cleaning and sanitizing, coatings, synthetic lubricants, cork adhesives, synthetic stopper materials, and research to stop TCA at the forest level, including TCA resistant bark. Packaging research for the beverage industry goes on for years and costs millions. How can the wine industry turn these issues around? "The only way I see it working is the cork suppliers and wineries approaching beverage packagers as a group; moving away from wine language and into language and parameters of beverage packaging, like ingress. Your industry is too fragmented; you want a perfect closure but can't technically define perfect; you have to tell the packaging industry what you want. What would you pay for corks with no TCA? Who is going to pay for the improvements?"

Crochiere declares that "the reject rates in this industry [average 3-4% TCA-taint] are absurd . . . I've worked for 20 years in the [beverage packaging] industry; and was shocked with your [industry's] failure rates; I've never seen anything like it in other packaging industries. Major beer bottlers tolerate no closure failure from their suppliers, or they shut them down."

The full text of seminar sessions from this conference is available online through *Vineyard & Winery Management* magazine, where the article was originally published, at: http://www.vwm-online.com//Magazine/Archive/2003/Vol29_No6/28thASEV.htm.