Cleaning and disinfecting barrels with high power ultrasonics: a new industry benchmark

Andrew Yap
Cavitus Pty Ltd

Validation trials by the Australian Wine Research Institute, University of Adelaide and University of South Australia, and extensive field trials at medium-sized and large wineries in California, Australia and NZ this year and last year have confirmed that Cavitus' high power ultrasonic (HPU) technology is highly effective in removing tartrates from barrels, while simultaneously killing viable *Brettanomyces* cells present on the surface and sub-surface of oak wood. Furthermore, this innovative technology has the added benefit of increasing the availability of desirable oak flavour volatiles that are present in the barrel's toasted layers.

By contrast, the application of conventional high pressure hot water (HPHW) cleaning technology showed highly variable cleanliness, but poor Brett kill, and is unsuitable for rejuvenation of heavily tartrated barrels. Furthermore, ozone – the chemical most commonly relied upon by the wine industry to kill Brett after the barrels have been cleaned with pressurised hot water – has been found to be seriously wanting. Because barrels typically represent the largest regularly recurring plant and equipment capital expenditure item for most wineries, the application of HPU represents a new approach to barrel sanitation that can bring about a significant improvement in winery net margins. Cavitus' HPU barrel cleaning and disinfection system (patent pending) has set a new benchmark to evaluate the performance of extant and future cleaning technologies.

Introduction

The maturation of wines in oak barrels results in the progressive coating of the barrel interior with tartrate precipitates. Studies by Cavitus have shown that there is positive correlation between the

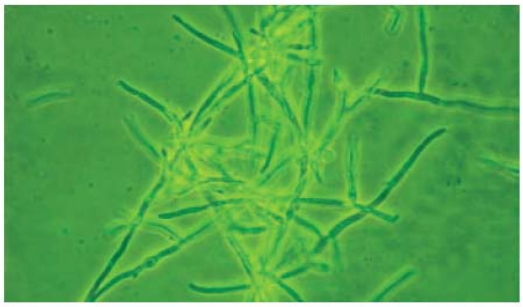

Figure 1. A photomicrograph of *Brettanomyces* (1000X), showing extensive psuedomycelia.

thickness and quantum of tartrate and the age of the barrel. Tartrate deposits not adequately removed during the cleaning process increase in thickness and hardness over time. In addition, dead and living spoilage microorganisms migrate into and clog the pores of the wood by capillary action. Psuedomycelia formation by Brett (Figure 1) assists in the organism's ability to migrate into and colonise pores and cracks, as well as empty spaces in the wood formed during the toasting process.

Current de-scaling treatments for barrels that typically use pressurised hot water and chemicals for disinfection are clearly ineffective, as evidenced by the rampant spread of the spoilage yeast *Brettanomyces* (Contero *et al.* 2006; Curtin *et al.* 2007). Pollnitz *et al.* (2000) found that wine stored in shaved and re-fired Brett-infected barrels contained 4-ethylphenol and 4-ethylguaiacol, confirming the presence of viable Brett cells in the wood. Boulton *et al.* (1996) have stated that barrels are often impossible to sterilise once they have become contaminated with spoilage microorganisms. Given that Brett can be found penetrating the wood at the same depth as the wine itself (Malfeito-Ferreira *et al.* 2004), there is to date no treatment capable of effectively decontaminating infected barrels – at least not without significantly impacting on the barrel's properties or its serviceable lifespan.

High power ultrasonic technology

HPU technology has become the benchmark for cleaning industrial equipment in the food, beverage and pharmaceutical industries (Patist and Bates 2008). HPU works by converting electrical energy to ultrasonic soundwaves above the range of human hearing of 12-20 Hertz. Within a liquid such as water, these soundwaves generate high-energy micron-sized bubbles, which subsequently collapse, creating shockwaves (that transfer kinetic energy), acoustic streaming, and vibration – this process is known as cavitation. The energies generated by cavitation disintegrate solids; remove layers of solid material or dirt from surfaces and porous interior structures; kill microorganisms on surfaces, in liquids, and in porous interior structures; reduce particle size; and prevent undesirable matter adhering to solid surfaces.

Cavitus, an Australian company, has successfully developed HPU for barrel cleaning. Its HPU mobile barrel cleaning and disinfection system is self-contained, and comprises a generator, transducer and

Figure 2. Cavitus' HPU mobile barrel cleaning and disinfection system (patent pending). Simultaneously, the barrel on the right is being sonicated, while the one next to it is being emptied, and an uncleaned barrel (second from left) is being filled. Ultrasound is delivered via a sonotrode inserted through the bung hole into the barrel that is filled with water at 60°C. Tartrate removal and destruction of *Brettanomyces* occur simultaneously during sonication. Water that is used for cleaning can be reused up to 100 times.

sonotrode for ultrasound production; diesel power generator for heating and electrical operations; a hot water storage tank; pumps for rapid filling and emptying of barrels; and a PLC unit. This efficient semi-automatic system simultaneously fills one barrel with water at 60°C and treats another with HPU, while emptying a previously sonicated barrel (Figure 2). The typical time required to sonicate a one-year-old 225-litre barrel is six minutes. Depending on the age of the barrel and its prior cleaning history, an older barrel may require eight minutes or longer; however, once a barrel has been treated with HPU, its subsequent cleaning with HPU would only take six minutes.

Tartrate removal

In-house testing by Cavitus and independent research undertaken by the University of South Australia in 2007 and 2008 confirmed that Cavitus' HPU system was more effective in removing tartrate deposits from the surface of one-year-old and three-year-old barrels when compared with HPHW systems (operating at 1000 pounds per square inch (6890 kilopascals) or 2000psi, and 60°C for five minutes). HPU removed more than 99% of the tartrates from the surfaces of one-year-old barrels after five minutes, in contrast to less than 20% removal in five minutes, and up to 50-80% after 12 minutes with HPHW. Complete removal of tartrate deposits from three-year-old old barrels was achieved by HPU between 10 to 15 minutes, depending on the quantum and hardness of the deposits; however, less than 50% removal was achieved by HPHW in the same time.

The efficacy of tartrate removal by HPU was further confirmed following extensive field trials in California last year and this year using Cavitus' HPU Beta prototype barrel cleaning and disinfection system (patent pending). A trial was undertaken with 16 red wine barrels representing two different ages – 2007 (two-year-old) and 2005 (four-year-old) – at a large winery. Details of the methologies used have been published (Yap and Bagnall 2009). HPHW was

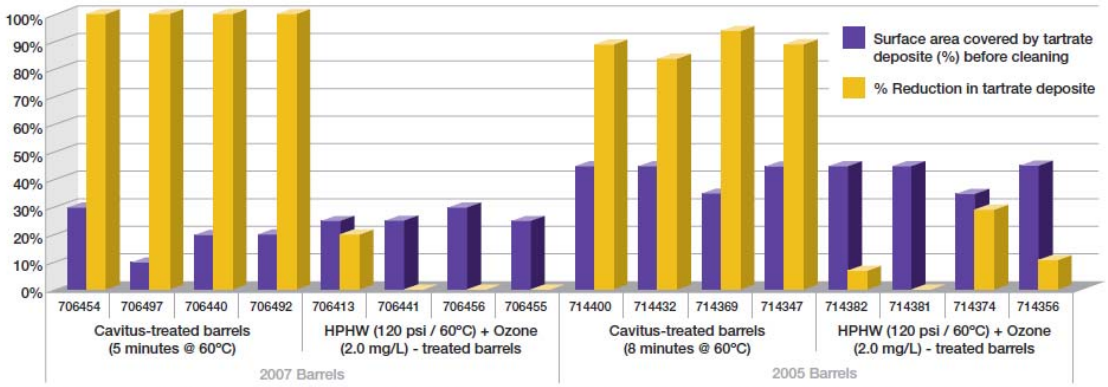

Figure 3. Removal of tartrate deposits by high power ultrasonic (HPU) technology and high pressure hot water (HPHW) cleaning technology from the surface of 2007 and 2005 red wine barrels.

employed at 120psi/830kPa and 60°C for two minutes, followed by ozonated water (2 milligrams per litre ozone) spray for one minute. For HPU, the 2007 barrels were sonicated for five minutes and the 2005 barrels for eight minutes. Data from this representative cleaning trial are presented in Figure 3.

Cavitus' HPU treatment consistently removed more tartrate than HPHW. The tartrate deposits in the 2005 barrels were hard to very hard, while those in the 2007 barrels were soft to hard. Initial area covered by tartrate deposits in the 2007 barrels ranged from 10-30%. Following Cavitus' HPU cleaning, all tartrates were removed (100% reduction) from all treated barrels. In contrast, HPHW only partially (less than 20%) removed tartrate from one barrel, while there was no reduction in three barrels. In the 2005 barrels, tartrates were reduced by 84–94% in HPU-cleaned barrels, compared to 0-29% in HPHW-cleaned barrels. This trial confirmed the effectiveness of HPU relative to a pressurised hot water system in removing tartrate build up.

A further attribute of Cavitus' HPU system is its ability to provide a uniform cleaning action, while HPHW does not. Figure 4 shows a heavily tartrate encrusted barrel before and after cleaning by HPU for eight minutes at 60°C.

Disinfection – the destruction of the common spoilage yeast *Brettanomyces*

Validation trials undertaken by the AWRI and University of Adelaide showed that Cavitus' HPU Alpha barrel cleaning and disinfection system inactivated all viable Brett cells on the surface (0-2 millimetres) and below the surface (2-4mm) of heavily infected new one-year-old and three-year-old oak staves. By comparison, the efficacy of HPHW in eliminating Brett was relatively poor (Yap *et al.* 2008). Only partially removing Brett allows the spoilage yeast to regrow and further contaminate wines and other barrels. The studies also showed the location of viable cells within the barrel environment determines their chances of survival, with populations within the arc between the headstave and bilge having the greatest opportunity to survive and proliferate.

To further confirm the effectiveness of HPU in eliminating Brett, a trial was undertaken at a Californian winery with 24 heavily Brett-infected barrels comprising eight of each of three different ages: two-year-old (2007), three-year-old (2006) and four-year-old (2005) barrels. The presence of viable Brett cells in these barrels was confirmed by Scorpion Microbial Assay (SMA) (Culbert *et al.* 2008). The barrels were divided into two sets, each comprising of four 2007, four 2006 and four 2005 barrels. One set was treated with HPU at 60°C for eight, 10 and 12 minutes for the 2007, 2006 and 2005 barrels, respectively. The other set was treated with HPHW at 300psi at 82°C for three minutes, followed by an ozonated water (3.5mg/L) spray for four minutes. Following treatment by the respective methods, the presence of viable Brett cells in the barrels was determined by plating and SMA.

The infected barrels contained large populations of viable Brett cells. Initial viable cell numbers present, as determined by SMA, ranged from 80,640 to 4.7 million cells per million litres. Barrels treated by Cavitus' HPU showed a dramatic reduction in cell numbers, viz. 99.96-100% (by plating) and 94.2-99.3% (by SMA). Barrels treated with 3.5mg/L ozone for four minutes after being subjected to 82°C pressurised hot water gave no reduction in viable cell numbers in eight out of the 12 barrels, and a low 21-47% kill in three barrels. Data from this representative trial verify the effectiveness of Cavitus' HPU to disinfect barrels, as confirmed independently by the AWRI and University of Adelaide. More importantly, the HPU system is significantly more effective in destroying Brett as compared to the current practice of HPHW and ozone treatments.

Preservation and enhancement of desirable oak flavours

A variety of desirable oak-derived flavour compounds are found in the toast layer of the barrel. Barrels cleaned by HPHW systems do not realise the full flavour potential because the most desirable flavours are contained within a thin layer (2-3mm) of toasted wood, and are either obscured by unremoved tartrates or destroyed. Shaving, dry-ice blasting and HPHW indiscriminately destroy the toast layer.

Data from preliminary studies showed that when unwooded red wines were matured in HPU- or HPHW-cleaned barrels, higher concentrations of furanic oak-derived compounds were found in the wines kept in HPU-treated barrels. Data from one such study during a 12-month period found that barrels cleaned by HPU retained more toasted oak flavour compounds than barrels cleaned by HPHW (1000psi at 60°C for eight minutes), as indicated by the significantly higher concentration of furfural in the Shiraz wines. The flavour compound furfural is an ideal performance indicator to compare the impact of different cleaning techniques, due to its desirability and scarcity in oak barrels (Garde-Cerdan and Ancín-Azpilicueta 2006).

The most likely reason for the increase in furfural yield in the HPU-treated barrels is its increased availability and rate of diffusion into the wine due to the removal of inhibiting layers of tartrate on the surfaces and pores. This finding suggests that Cavitus' HPU treatment of barrels may shorten the maturation time necessary for the wines to attain the desired oak characteristics. Furthermore, the lower furfural

Figure 4. The surface of a five-year-old barrel before cleaning by Cavitus' high power ultrasonic (HPU) technology system on the left (the tartrate deposit is thick, hard and crusty). The photo on the right shows the uniformly cleaned surface of the barrel after eight minutes sonication time by HPU.

concentration in HPHW-cleaned barrels may be due to the removal of toasted compounds attributed to damage or removal of the thin toast layer caused by jets of HPHW. Typical of HPHW cleaning is the presence of patches of oak surfaces with a furry appearance, suggesting damage and removal of the important toast layer. Studies are in progress to confirm that HPU can enhance and preserve oak-derived flavour compounds during the life of the barrel.

Conclusion

The benefits of HPU over pressurised hot water and chemical treatments in cleaning and disinfecting barrels are many-fold. HPU is by far a more effective way of removing tartrate deposits and solid residues, facilitating greater exposure of the wine to the oak and maximising the amount of air which can infuse into the wine via stave capillary action. This maximises the quantity and quality of oak flavour compounds imparted to the wine. HPU is also the most effective way of disinfecting barrels, with its capacity to destroy spoilage microorganisms both at the surface and sub-surface levels, therefore ensuring highly infected barrels are free of viable Brett cells. Such efficient cleaning and disinfection greatly increases the life of the barrel, resulting in saved costs in new oak.

Importantly, HPU employs a one-step process (this greatly reduces time, energy and water resources), whereas traditional pressurised hot water and chemical treatments require a minimum two-step process. The fact that HPU uses significantly less water and requires no chemicals greatly reduces the impact on the environment, as well as the occupational health and safety risk. For all these reasons, HPU now sets the benchmark in barrel cleaning and disinfection.

Economic analysis shows that the cost of cleaning a barrel with Cavitus' HPU technology is less than that of HPHW. Wineries not wishing to purchase a unit would benefit from using a mobile service provider. A South Australian company, Wine Barrel Cleaning Solutions, has been licensed to use the technology to provide a mobile service to the wine industry. The unit has been demonstrated in SA and Victorian wine regions, and visits are scheduled for New South Wales, Western Australia and Tasmania in Q2 and 3, 2010. ■

References

Boulton, R.B., Singleton, V. L., Bisson, L. F. and Kunkee, R. E. (1996) Principles and Practices of Winemaking, Chapman and Hall.

Conterno, L., Joseph, C.M.L., Arvik, T.J., Henick-Kling, T. and Bisson L.F. (2006) Genetic and physiological characterization of *Brettanomyces bruxellensis* strains isolated from wines. American journal of Enology & Viticulture (57): 139 – 147.

Culbert, J.; Gishen, M.; Day, M. and Oemcke, D. (2008) Taking the sting out of spoilage. The Aust. NZ Wine Industry J. 23(6): 47–50.

Curtin, C.D., Bellon, J.R., Henschke, P.A., Godden, P.W., de Barros Lopes, M.A. (2007) Genetic diversity of *Dekkera bruxellensis* yeasts isolated from Australian wineries. FEMS Yeast Research (7): 471-481.

Garde-Cerdan, T. and Ancin Azpilicueta, C.(2007) Review of quality factors on wine aging in oak barrels, Trends in Food Sci. Technol. 17: 438 – 447.

Malfeito-Ferreira, M., Laureano, P., Barata, A. and Dutuono, I.D. (2004) Effect of different barrique sanitation procedures on yeasts isolated from the layers of wood. In Technical Abstracts of the 55th Annual Meeting of the American Society for Enology and Viticulture, San Diego, California, p 34. American Society for Enology and Viticulture, Davis, CA.

Patist, A. and Bates, D. (2008) Ultrasonic innovation in the food industry: From the laboratory to commercial production. Innovative Food Science and EmergingTechnologies 9: 147-154.

Pollintz, A.P., Pardon, K.H. and Sefton, M.A. (2000) 4-Ethylphenol, 4-ethylguaiacol, and oak lactones in Australian red wines. The Australian Grapegrower and Winemaker 438: 45-52.

Yap, A. and Bagnall, W. (2009) High power ultrasonics: a new and powerful tool for removing tartrate deposits and killing viable *Brettanomyces* cells in barrels. The Australian and New Zealand Wine Industry Journal 24(5): 29-39.

Yap, A., Schmid, F., Jiranek, V., Grbin, P. and Bates, D. (2008) Inactivation of Brettanomyces/Dekkera in wine barrels by high power ultrasound. The Australian and New Zealand Wine Industry Journal 23(5): 32-40.

Acknowledgements

Cavitus Pty Ltd wishes to thank the Australian Wine Research Institute, University of Adelaide and University of South Australia for providing assistance in the research cited in this article. Many wineries in California, Australia and New Zealand participated in the field trials. Valuable information has been generated from these trials using a groundbreaking technology. The author would like to thank all personnel involved during the past two years.

Andrew Yap is director of Oenology and Industry Marketing at Cavitus Pty Ltd. He can be contacted by phone on (08) 8425 9602 or 0414 953 116, or by emailing ayap@cavitus.com. More information about Cavitus' HPU barrel cleaning and disinfection system – static or mobile – and demonstrations in Australian wine regions are also available at www.cavitus.com.