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Corresponding Author
Julian Alston

E-Mail
julian@primal.ucdavis.edu

Affiliation
UC Davis

Co-Author/s

Name	E-Mail	Affiliation
Torey Arvik	Torey.Arvik@wholevine.com	Sonomaceuticals, LLC
Jim Lapsley	jtlapsley@gmail.com	UC Davis

Keywords
winemaking, total quality management, Brettanomyces, testing and treatment, technological innovation, California wine

Research Question
What are the costs of Brettanomyces in wine and what are the benefits from improved methods for testing and treatment, and total quality management?

Methods
Analysis based on detailed data from individual wineries on rates of infection with Brettanomyces and the costs and benefits of alternative testing and treatment regimes

Results
Brettanomyces imposes very large costs on wine producers but can be managed economically using improved (precision) technologies and information-based management protocols.

Abstract

Improvements in technology of winemaking over the past 20 years and more have significantly reduced the incidence of various faults in wine. At the same time, however, the wine-consuming public and wine experts are better educated about these faults and better at spotting them. Since even advanced winemaking still uses traditional methods and materials, the risk of these flaws remains a threat. Economically important faults are associated with the presence of excessive amounts of particular odor-active chemical compounds including those associated with cork taint (2, 4, 6, Trichloroanisole or TCA), oxidation (mainly ethanal), volatile acidity (mainly acetic acid), and ethylphenols, generated by Brettanomyces bruxellensis (4-ethylphenol and 4-ethylguiacol). At low concentrations these chemicals might not be discernible, or not a bother, and in some instances some amount may even be desired by some consumers. A fault, then, reflects an excessive amount of these compounds relative to that desired by the winemaker, the quantity that will maximize the value of the wine in question. In turn this depends on consumer preferences and perceptions. However, consumers' perceptions of a particular fault differ by wine variety, winemaking style, bottle price, personal experience, and so on, making the winemaker's optimization problem more complicated.

Winemakers use various methods to manage these potential faults, all of which rest on some procedure for early detection and timing of treatment. In this paper we estimate the costs of Brettanomyces in wine produced in California, and the benefits from improved technologies for early detection and treatment. As well as being of specific interest, this work serves as a case study exemplifying the more general issue of the costs of wine faults

and the benefits from precision winemaking technology that reduces the incidence of those faults and their costs.

Brettanomyces bruxellensis, or Brett, is a yeast that exists naturally in wineries and vineyards throughout the world. The winemaking process selects for Brett in the winery. Once the yeast is well established in the winery environment it is hard to eradicate and is spread readily and maintained by improperly sanitized equipment. Wood barrels are a key factor in the persistence of Brett in a winery. Early detection of ethylphenols or DNA signatures of Brett can improve winemakers' control of it. If Brett is detected, barrels are typically washed, sanitized with hot water, ozone and in some cases steam, and then returned to production until they lose value enough to remove them from the winery (year 3–5). The blending of infected wines at this stage is the primary cause of spread in the winery. Filtration is the most effective method to decrease risk at this stage. The important economic questions concern how best to detect the problem and treat the infected wine prior to a loss of quality.

When Brettanomyces grows in wine it produces several compounds that can alter the palate and bouquet. The four most important known aroma active compounds are 4-ethyl phenol or 4-EP (described as having the aromas of Band-aids®, antiseptic, barnyard, and horse stable); 4-ethyl guaiacol or 4-EG (described as having aromas of smoked bacon, spice or cloves); 4-ethylcatechol or 4-EC (described as having a horsey aroma); and isovaleric acid (described as having an unpleasant smell of sweaty animals, cheese and rancidity). Other aromatic characteristics associated with Brett include wet dog, creosote, burnt beans, rotting vegetation, plastic and (but not exclusively caused by Brett) mouse cage aroma and vinegar. Different strains of Brett can produce varying amounts of any of these compounds. Further, the variety of grape used for the wine can greatly influence the production of fault-specific compounds.

At low levels, for some consumers, the presence of these compounds has a positive effect on wine, contributing to complexity, and giving an aged character to some young red wines. Some wines even rely on Brettanomyces to impart a distinctive character. However, when the levels of the sensory compounds greatly exceed their sensory thresholds (which vary among wines according to their style and structure), their perception is almost always negative. Sensory thresholds differ among individual consumers, and some find the compounds more unattractive than others, which may relate to cultural experience. While Brett character can be desirable at lower levels, there is no guarantee that high levels will not be produced unless the yeast is killed or physically removed. As Brettanomyces can potentially spoil a wine it is generally seen as a wine-spoilage yeast, a risk to be actively managed, and the presence of its metabolites as a wine fault.

When Brettanomyces or its spoilage by-products are detected in wine, the winemaker has some treatment options available, including doing nothing. The "do-nothing" option could result eventually in the loss or downgrading of an entire tank, barrel group or lot of wine. Subsequent losses of bottled wine may also occur over a period of months or years as Brettanomyces can subsist in wines for decades. The impact might be seen ultimately as damage to a brand or wine company. The reduction in future willingness to pay for wine by consumers who, having perceived a fault (or perhaps simply a flavor they do not like) in the wine, are less confident of the quality and perceive a higher risk of disappointment with future purchases. This reduction in demand may be confined to the particular wine brand or the winery that produced it, but might extend more broadly as an externality in the industry—a type of reputation effect potentially calling for a broader approach to quality management. (Wineries in the Hunter Valley region in Australia undertook a Brettanomyces eradication program because the producers there saw this externality problem as a serious problem for the regional industry.) The "do-nothing" option is also the default option if the winemaker fails to detect the problem because the technology for detection is ineffective.

Improved technology allows for earlier detection and a broader range of treatment options that can mitigate the damage—both to the current vintage and, through reputation effects, to future vintages. The growth of Brettanomyces can be controlled by the addition of sulfur dioxide, to which, some strains are becoming more resistant, or other sterilizing compounds such as dimethyl dicarbonate (Velcorin®) at bottling. Alternatively the wine can be bottled after sterile filtration, which physically removes the yeast. Either of these treatment strategies might have consequences for other aspects of wine quality that must be taken into consideration. Filtration has the potential to remove Brett but also may remove or change important textural components, potentially making the wine less interesting (though, in a blind sensory study comparing filtration with non-filtration on wines from other wineries, winemakers could not reproducibly identify a change in the majority of cases). Filtration physically removes the risk and is the best option from a risk and quality assurance position. Velcorin® treatment preserves the texture and kills Brett, but there is a sense with some winemakers that sterilization destroys the natural fate of the wine. Because Velcorin® degrades rapidly, thus allowing potential reinfection, it is generally only used immediately prior to bottling. High doses of sulfites will deaden the varietal aromas and prevent the aging process, changing the experience for those who try to enjoy the wine too soon after production.

Controlling the infection does not eliminate the already present spoilage by-products. It may be economical in some cases to blend the wine with other (typically lower-valued) wine to dilute the fault compounds—effectively downgrading the infected wine and reducing value. This is one measure of the loss of value. A more challenging measure of loss of value is the potential effect on consumer willingness-to-pay for other wines, both from the same vintage and future vintages, for the particular winery and across the industry.

The analysis of this paper uses detailed (confidential) data from wineries in California to document the consequences of Brettanomyces for the economics of wine production using typical current technology, depending on the prevalence of the problem—the costs of preventive measures, detection and treatment; the costs of mitigation in terms of the loss in value of wine that has to be downgraded. These economic consequences provide a baseline against which we can measure the benefits from using new technologies that permit earlier detection and treatment. These new technologies include genetic tests for the presence of Brettanomyces at very low cell densities and advanced chemical tests for low concentrations of the spoilage by-products. The technologies are perceived by winemakers as expensive and are not necessarily economical for every winery or every wine. However, the cost of testing must be weighed against the risk of spoilage.

Our analysis at the level of individual wineries explores the determinants of the costs, benefits, and optimal choice of detection technology and testing and treatment strategy for Brett, including (a) the frequency of testing of individual lots of wine (and the sampling strategy to be employed, including the size of batches being tested, and so on), (b) the scale of the winery in terms of total value and volume of wine being produced, (c) the type(s) of wine being produced (different varieties and styles being more or less susceptible), (d) the prevalence of the problem in the winery currently (which might not be known) and in the past (which may be known), and (e) the potential value per unit of the wine (which affects the scale of the loss from being downgraded). In addition to exploring these micro-level differences, we extrapolate from our analysis of winery-specific data to infer a value of the technology and the costs of Brettanomyces to the California wine industry as a whole.

Some References

MacLachlan, M.J., M.R. Springborn, and P.L. Fackler. “Learning About a Moving Target in Resource Management: Optimal Bayesian Disease Control.” American Journal of Agricultural Economics (early access June 20 2016) http://ajae.oxfordjournals.org/content/early/2016/06/17/ajae.aaw033.full.pdf+html

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The Economics of Precision Winemaking: General Concepts and Application to Testing for *Brettanomyces* in California

Julian M. Alston, Torey Arvik, and James T. Lapsley[1]

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American Association of Wine Economists annual conference,
Padua, Italy, June 28 – July 1, 2017

Improvements in technology of winemaking over the past 20 years and more have significantly reduced the incidence of various faults in wine. At the same time, however, the wine-consuming public and wine experts are better educated about these faults and better at spotting them. Since even advanced winemaking still uses traditional methods and materials, the risk of these flaws remains a threat. Economically important faults are associated with the presence of excessive amounts of particular odor-active chemical compounds including those associated with cork taint (2, 4, 6, Trichloroanisole or TCA), oxidation (mainly ethanal), volatile acidity (mainly acetic acid), and ethylphenols, generated by *Brettanomyces bruxellensis* (4-ethylphenol and 4-ethylguiacol). At low concentrations these chemicals might not be discernible, or not a bother, and in some instances some amount may even be desired by some consumers. A fault, then, reflects an excessive amount of these compounds relative to that desired by the winemaker, the quantity that will maximize the value of the wine in question. In turn this depends on consumer preferences and perceptions. However, consumers' perceptions of a particular fault differ by wine variety, winemaking style, bottle price, personal experience, and so on, making the winemaker's optimization problem more complicated.

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[1] Julian Alston is a Professor in the Department of Agricultural and Resource Economics and Director of the Robert Mondavi Institute Center for Wine Economics at the University of California, Davis. Torey Arvik, PhD is Chief Scientist at Sonomaceuticals, LLC, St Helena, CA. Jim Lapsley, PhD is an Academic Researcher at the University of California Agricultural Issues Center in Davis, CA.

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