Understanding Microbial Terroir in Wine

Ongoing studies suggest that vineyard-specific microorganisms affect wine character. But does that mean natural wine is more expressive of terroir?

Illustration by Jeff Quinn.

Terroir has long been a hot topic in wine, but now the lens is zooming in even further. *Microbial* terroir—or the effects of bacteria, yeast, and other microorganisms in a vineyard—has become central to the conversation about overall terroir, particularly to the debate over natural wine and how we define it. The idea behind microbial terroir is that the microorganisms of a vineyard are unique and affect wine character in distinct ways, making them essential components of the expression of a site.

Research in this area is only beginning, and because of the complex nature of vineyard microbes and their possible effects on fermentations and wine character, concrete answers probably won't be available for some time. The research so far, though, supports the influence of microbial terroir, prompting a myriad of interesting questions about the manner in which a wine channels the place it's from.

To what degree do a vineyard's unique microbes influence a wine's character? Is a "pure" microbial expression of terroir even possible? Do inoculated fermentations—in which a winemaker introduces a cultured yeast strain not originating from the vineyard site—preclude true expression of terroir? Are natural wines, which are made by spontaneous fermentations and don't have cultured yeast added, inherently more authentic representations of their vineyard origins? Answers to these questions are beginning to emerge.

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Groundbreaking Microbe Research

In the last few years, many studies have been conducted on wine biogeography—the study of the geographic distribution of wine microbiota—and the microbial consistency of vineyards, vintages, and regions. There appears to be a degree of fluctuation in populations of microbes by vineyard and by vintage, but on the larger scale of geographic areas, these populations appear to be quite stable.

In 2016, Nicholas Bokulich and his colleagues at the University of California at Davis took wine biogeography studies a step further. After identifying microbial populations on Cabernet Sauvignon and Chardonnay grapes from Napa and Sonoma vineyards, the team tested population shifts throughout the winemaking process, and, for the first time, studied the resulting metabolites (compounds thought to be produced by the various microbes) in each wine. They focused on the metabolites they felt were most likely to affect wine aroma, although actual sensorial effects were not measured.

“We demonstrate that the grape/wine microbiota and metabolites are regionally distinct,” the researchers said in their study, “and grape must microbial composition predicts the metabolite composition of the finished wine, suggesting that microbial

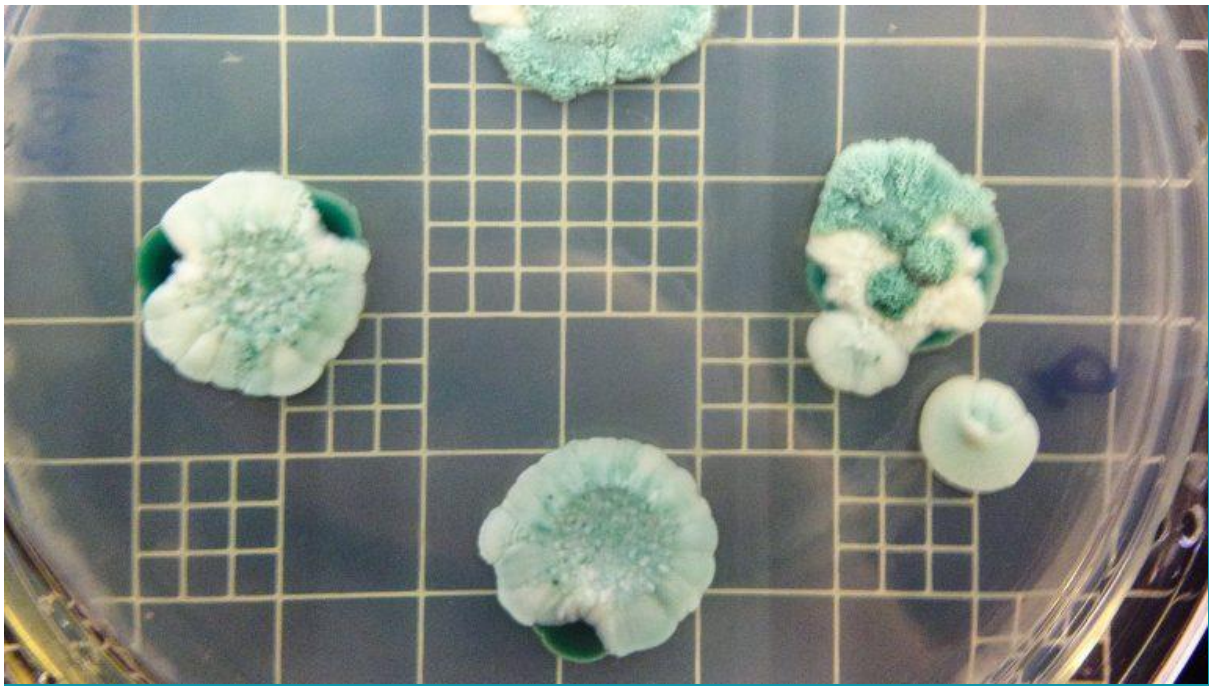
dispersion patterns may contribute to regional wine characteristics." The results allowed computer software to quite accurately predict which wine came from which vineyard, based on the presence of specific metabolites.

Producers of natural wine, who place great importance on the concept of microbial terroir, do not inoculate fermentations with commercial yeast, and often forgo the use of sulfur dioxide (SO_2) entirely, or at least until bottling, in large part to ensure that the microorganisms from the vineyard leave their mark on the wine. However, in contrast to these natural winemaking principles, the wines in the U.C. Davis study were inoculated with commercial yeast *and* dosed with SO_2 before fermentation; additionally, the Cabernet Sauvignon was inoculated with malolactic bacteria. The vineyard microbiota were found to have left their chemical signature on the wines despite practices commonly thought to eradicate them.

Though the aim of the study was not to examine the use of commercial yeast and bacteria, Bokulich feels that the revelation that their use didn't suppress the influence of the microorganisms could "potentially break the dogma that inoculation overwhelms any terroir signal." He notes, however, that the influence may be observable chemically but not sensorially. In theory, it could be argued that wines not inoculated may have higher concentrations of these metabolites, potentially leading to a louder "signal."

"This is a groundbreaking study," says Dario Cantu, a plant pathology professor at U.C. Davis, "but we definitely need more

research to define the mechanistic relationship between microbiota and [character] of the finished wines."



Pictured here is a plate Cornell student Marie Guido-Miner created when she was cataloging environmental and vineyard microbiota. Photo courtesy of Marie Guido-Miner.

Microbiota in the Vineyard

While the latest research implies that we should treat microbes as part of terroir, they are an aspect of terroir unlike all the others—such as weather, soil, slope orientation—in that the microbiota is not fixed at the time of harvest. Studies have found that the microbial mix—the types and proportions of microbes present—changes as grapes ripen. If the microbe population on grapes changes during ripening, then there would be no set "microbial terroir" for a given site. Just as grape character changes through ripening, the population and effects of the vineyard microbiota will change as well.

Although the general population of microbes has proven to be fairly stable within geographic areas, there is evidence that farming practices affect the microbial mix. All farming strategies and products affect a vineyard's microbiota; even if a treatment is organic, for instance, it will have a unique effect on the mix of microbes. This adds the microbiota to the long list of factors in wine production that are affected by human choices and that therefore affect a wine's final composition. In other words, because a wine's chemical and sensory composition are unavoidably affected by human interventions, a pure expression of terroir—including microbial terroir—that is free of human influence cannot exist.

What's Fermenting My Wine?

The study of microbial terroir and its impact on wine character is further complicated by the fact that even if a winemaker adds no cultured yeast, it is almost impossible to ensure that the microbes from the vineyard are the *only* ones fermenting the wine.

Take the yeast *Saccharomyces cerevisiae,* for example—the star of alcoholic fermentation. Nearly every wine fermentation, inoculated or not, becomes dominated by *Saccharomyces,* which ferments most of the sugar in wines and brings wine to dryness. But where does this *Saccharomyces* come from in spontaneous fermentations?

"There is very little *Saccharomyces* on healthy grapes," says Anna Katharine Mansfield, an associate professor of enology at Cornell University. Although *Saccharomyces* is a rarity on healthy grapes, it is extremely common all over the world, found on everything from bees to transport trucks. In spontaneous fermentations, this critical

yeast almost always comes from the winery's building's resident population (though there is a small chance it could come from the vineyard).

The typical scenario with spontaneous fermentations goes like this: Fermentation starts from microorganisms (usually non-*Saccharomyces* yeasts and bacteria) that more than likely originate in the vineyard. As the microorganisms quickly die off because of increasing alcohol concentrations, most dying between 1% to 3% ABV, *Saccharomyces* (which can survive up to 15% ABV and higher) takes over and is responsible for most of the fermentation. Though these spontaneous fermentations are often called native fermentations, the phrase is misleading; native vineyard microbes are most likely never alone or able to complete the fermentation on their own.

Still, this is an oversimplification. "We make a lot of assumptions about what's happening microbiologically in our wines," says Mansfield. "At the end of ferments, we expect to find only *Saccharomyces,* but the few people who have explored what's present at the end of fermentation have found more diversity than expected. We even find some weaker strains we expect would be gone—inoculated or not."

Peter Hunken, the proprietor of Black Sheep Finds and The Joy Fantastic winery and vineyard in Santa Barbara County, California, has been surprised when testing active fermentations to see which specific yeasts are at work. Hunken takes a hands-off approach to winemaking, opting for spontaneous fermentations, but his tests

have revealed unique, unidentified subspecies of *Saccharomyces cerevisiae* at work midway through fermentation. More research would be needed to determine the origin of these yeasts, but Hunken's results further emphasize the complicated nature of fermentation at a microbial level.

On the left is inoculated ferment, and on the right is spontaneous ferment. Photo courtesy of Black Sheep Finds.

Microbial Effects in the Glass

How much of a wine's story is told by the grape itself, and how much is the result of the vineyard's unique microbes? Is the impact of microbes subtle or critical to the creation of a terroir-driven wine? An understanding of the origins of wine aromas is important for this discussion.

The primary aromas of grapes are formed in the grapes and are therefore present at harvest. During fermentation, microorganisms

liberate these aromas from their bound, or nonaromatic, form in the grapes, rendering them volatile, or able to be smelled. Different yeast strains will liberate different proportions of aromas, but overall, this nonmicrobial terroir coming from the grapes is incorporated into the wine. Different yeast strains do lead to unique esters—which is one of the reasons commercial yeasts have been demonized in natural wine circles—but these break down almost entirely after about a year of a wine's life and largely cease to contribute to long-term wine character.

In general, wines fermented with neutral commercial yeasts seem to have a higher degree of aromatic delineation and precision, which could be attributed to the smaller pool of organisms at work, which are leading to larger proportions of a smaller set of compounds. Clean, spontaneously fermented wines often have more depth and nuance. This may be attributable to the greater diversity of organisms involved—which therefore lead to more diverse compounds—and perhaps also to the slower and cooler fermentation that often results in spontaneous ferments.

The attempt to harness vineyard microbiota for spontaneous fermentation is both a noble pursuit and a risky process, however. Spontaneous fermentations do not have a fixed result. While their success depends on the care taken by the winemaker, even the most talented winemakers experience occasional fermentations that develop perceptible defects—the two main culprits in the case of such fermentations are volatile acidity (acetic acid, or vinegar) and ethyl acetate (nail polish remover).

When compounds considered to be defects are below or around sensory threshold levels, they may contribute positive qualities to a wine, but past a certain, admittedly subjective point, they can overshadow the character of the grape—and vineyard—itself.

The Full Terroir Story

If every wine tells a "terroir story," a clean spontaneous fermentation gives us the full narrative. It provides the most precise representation of vineyard character—dirt, weather, microbes, and all. An inoculated fermentation may leave out some of the finer points of the story—the microbial points—but overall, it still gives a good representation of the vineyard.

But *unclean* spontaneous fermentation, in which defects begin to hinder our ability to clearly perceive vineyard character, is more like a censored terroir story, a story in which a black marker has obscured some portion of the text. In this way, an unclean spontaneous fermentation can have masking effects similar to those of excessive oak, heavy *Brettanomyces,* oxidation, or overripe fruit that leads to generic fruit character.

Of course, wines with these characteristics can sometimes be beautiful—many famous, world-class wines have them. But the wines have lost, to some degree, their ability to accurately and completely demonstrate their terroir. This is a philosophical point, not an aesthetic one.

How Big Is The Role of Microbes?

Though no concrete determinations have been made on the exact contribution microbes make to a finished wine, Reid Griggs, a U.C. Davis graduate student working with David Mills, one of the Bokulich study researchers, explains that the effects are probably significant. He suggests imagining "the differences in production of a single metabolite—acetic acid or [alcohol level], for instance—by different yeast strains in the same must. Each will produce slightly different concentrations of these primary sensory components from the same must. When you expand this to the whole ecosystem of microbes and chemical species in wines, the permutations of possible results are immense."

Although the majority of a wine's expression of terroir in the glass is determined by factors like grape variety, weather, and soil, the little fellows that hitch a ride on the grape skins do seem to play an important role. As a winemaker and importer who tastes a lot of wine, I imagine that the grapes themselves contribute 85 to 90 percent of a wine's character, therefore making the contribution of the microbiota subtle but significant. A well-made wine, whose grapes are picked at reasonable ripeness, from a vineyard with a distinct character, should taste like that vineyard, regardless of what ferments it.

Research in this area will be slow to emerge (most funding goes to studies that protect industry viability and efficiency, like disease resistance and irrigation technology). But as new insights become available, we will begin to further deepen our understanding of what's happening microbially in our favorite beverage.

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