

American Microbial Terroir

by Ben
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MICROBES IN FOOD are all the rage these days. I'm not talking about *Listeria*-laden cantaloupes or *salmonella*-infused peanut butter. I'm talking about "good" bacteria—yeasts and molds that have the molecular machinery to transform relatively bland food substrates into delicious fermented foods. You might even say that a fermentation revolution is sweeping across the country, with Americans from Brooklyn to Oakland dedicating entire sections of their homes to the odoriferous and often unpredictable world of fermented foodstuffs. If you don't have a crock of rotting cabbage in the corner of your kitchen, you just aren't cool anymore.

In the Momofuku test kitchen, we've been helping David Chang and his lab chefs develop microbial recipes to beautifully rot rice into *koji*, grains into miso, and pork into *katsuobushi*. We're teaching these chefs how to use invisible ingredients—native New York yeasts and molds isolated in their kitchen—to ferment foods that are usually made with commercial microbial strains. Chang is so excited about microbes that he is traveling around the world giving lectures in which he declares that microbes are the future of American cuisine. To a microbiologist, hearing a chef get excited about *Aspergillus oryzae* and *Neurospora sitophila* is mind-blowing.

One of the reasons people are so intrigued by fermentation is that these microbes in the air, soil, and water in our own backyards can actually contribute to regional flavors. Just as the soil and climate of a particular region create the *terroir* of a wine, regional

microbes can create signature flavors, too. This notion is something that Chang and others have called *microbial terroir*. Different species of microbes have different ways to make flavor molecules as they break down raw ingredients into smaller pieces. If two producers in two different locations use almost identical raw ingredients, but one has ten different microbes growing on his or her product while the other has only five, you can expect different flavors to result.

Microbial terroir is currently just a buzz phrase in the artisanal food movement; there is no scientific data to back it up. In America, we know almost nothing about the microbial biodiversity of our fermented artisanal foods, so it's impossible to know how microbes vary from one place to another. Even for American artisanal cheese or sourdough bread, in which microbial terroir is implied, we have absolutely no data on what microbes

play a part in these foods.¹ As with all things food, the microbiophilic Europeans are way ahead of us, and have done hundreds of studies documenting how bacteria and fungi vary from one food-production region to another. They've even gone as far as suggesting that they need to protect regional food microbes just as regional foods are protected.

As a card-carrying microbiologist, I can tell you that the idea of American microbial terroir is not at all crazy. It rests on two basic assumptions: 1) microbial diversity is different in different regions of America; and 2) microbes that colonize food play as much of a role in producing flavors as do the raw ingredients that go into that food. We know both of these things are true. Scientists have recently shown that the microbial diversity of the air, soil, and water is extremely different from one part of the United States to another, even in places just a few miles from each other. This diversity also changes throughout the seasons. We also know from studies in Europe that a huge amount of the flavor in cheeses, fermented sausages, and other foods comes from microbes, and that different combinations of microbial species lead to completely different flavor profiles.

So if we were going to attempt to track down and exploit the elusive microbial terroir in our pubescent

culinary landscape, where would we look and how would we try to define it? We'd want to start with a fermented food that's made in different places throughout the country. We'd want a food that isn't heavily seasoned or manipulated, so that the microbial transformation of the food is the primary source of flavors. And we'd want something where microbes from the environment could freely colonize the surface of the food and contribute substantially to the flavor. What we want is American artisanal salami.

In the past five years, a handful of producers have popped up around the country, making salami that are truly American, but that also reflect traditional European styles. While the composition of the meat, spices, wine, and herbs provide body to the salami, the microbial degradation of the meat through the production of enzymes is the key to creating signature flavors. To the average person, the outside of salami is just a dusty white jacket. But it actually comprises millions of microbial cells that have accumulated over time, as the salami has aged. This microbial ecosystem transforms an intestine full of raw meat into a perfectly petrified expression of porkiness. When food scientists try to age salami without microbes, they just get a rancid intestine full of sad meat.

In the first stage of salami production (usually just a day or two), lactic-acid bacteria (similar to those found in yogurt and cheese) rapidly acidify the raw meat that has been stuffed into the sausage casing. This acidic environment,

in addition to nitrites/nitrates that are added to the meat, prevents bad bacteria from growing and adds a lactic tang to the flavor of the finished sausage. Generally, this process is highly controlled to ensure that the food is safe. There are only a few microbe cultures available for this stage (mostly *Lactobacillus*, *Pediococcus*, and some *Staphylococcus* species), so flavor profiles don't vary too much from one producer to the next. Consider this the boring stage of salami microbiology.

But after this first one- or two-day fermentation, salami are hung in a cool, humid environment where they slowly lose moisture. This is where it gets really interesting. Over a period of weeks or months, a fuzzy and sometimes bumpy rind will develop on the casing. Much of the fuzziness comes from molds that are either added (*Penicillium nalgiovense* is generally the mold of choice) or that naturally colonize the salami from the air. The molds help mediate the drying process, and can also add a level of mushroomy earthiness to the salami. Nestled within this mold forest are much tinier cells of yeasts and bacteria that also colonize the casing from the air. Based on studies in Europe, we know these bacteria are generally different species of *Staphylococcus*. (Don't worry, they have no relation to the *Staphylococcus* or "Staph" species known as MRSA, which is often in the headlines for killing people. While a few species of *Staphylococcus* can make people really sick, many are benign.)

¹ While the FDA does routine inspections of some fermented foods for pathogens, the good microbes are never studied. It's sort of shocking, considering that the good microbes might help get rid of the bad microbes.

The yeasts are typically *Candida* and *Debaryomyces* species. All of these microbes release enzymes that break down the meat under the casing. This process of intentional rot leads to the production of compounds that we perceive as flavors in the meat, such as acetoin (creamy butteriness), various esters (fruity yeastiness), and branched-chain aldehydes (typical aged-meat/cheese flavors). As the salami loses moisture, these microbial flavors become more concentrated.

Not all microbes break down meat in the same way. Some species are better at breaking down fats, while others have the machinery to efficiently break down proteins. And even within each of those categories, there are many ways to rot a piece of meat. So the presence of a particular microbe on your salami can have a strong influence on the overall appearance and flavor of the salami.

To search for microbial terroir in American salami, I purchased samples from five different producers in North America. (To make sure the sampling was representative, I bought three to four separate salami from each producer.) I wanted to be able to detect differences in flavors due to the presence of microbes, so I tried to get those salami with the least amount of spices or other flavors added. I asked a bunch of my food-loving friends in Boston (my chef husband, his chef friends, and other food-science nerds) to eat

the salami with me, and to describe the type and intensity of different flavors (sweet, sour, salty, porky, rancid) they perceived. Food scientists call this sensory analysis. I also isolated the bacteria and fungi from the outside of each salami, and sequenced the DNA of these isolates to identify their microbial-species diversity.

Two big patterns emerged from this exercise. First, while there is a core set of microbes found across all salami (if you build it, they will come), there are also specific microbes that are unique to specific producers (hello, microbial terroir!). The relative amounts of the different species and types of microbes (bacteria versus mold versus yeast) also varied from sausage to sausage. You can easily see this by scanning the circles in the figure showing the bacteria and fungi that I isolated (see page 107). Some microbe colonies are common across the five salami, while some are clearly unique.

For example, all salami included the yeast *Debaryomyces hansenii*, the most commonly found yeast on European salami, which is also often found on North American cheeses. They also all had the mold *Penicillium nalgiovense*, probably because they were all inoculated with this strain—a standard practice in the industry. But the salami from Berkeley, California, was super yeasty due to the presence of *Candida deformans*, which produces rustic, funky-barnyard volatile compounds when grown in isolation. The salami from Utah was the only sausage to have the yeast *Candida zeylandoides*,

a species seen on some European salami and raw cheeses.

Another interesting pattern was the relationship between flavor complexity and microbial diversity. The least microbiologically interesting salami was the salami from Oakland, California. That thing was packed full of the mold *Penicillium* and a few yeasts, but had almost no bacteria growing on the casing. It was by far the mildest-flavored salami. It was fine—it tasted like salami—but it didn't have intense flavors that really set it apart from the rest. It's likely that the lack of bacteria leads to a loss of the distinct flavor molecules that can increase the complexity of the flavor.

If the salami from Oakland was the microbial equivalent of a well-manicured golf course, then the salami from Oregon was a freaking jungle. This salami had four different species of *Staphylococcus*—more than any other salami I looked at—and had its own unique mold (a species of *Scopulariopsis*) that wasn't found on any other salami. Looking under the microscope, the Oakland salami looked like a homogenous snowy field, while the Oregon salami looked like a scene from *Where the Wild Things Are*. The Oregon had the funkier flavor profile of all the salami we tasted. Some tasters noticed hints of barnyardy-umami-mushroom, while others were talking about burnt chocolate and butter.

There was also obvious variation in flavor production among different strains of the same species. The bacterium *Staphylococcus succinus* from

Oregon produced more buttery notes than the same species isolated from the Virginia salami. So even if the same species is present, regional differences can still appear.

So there you have it. Microbial terroir exists in America! Let the microbial marketing continue and the fermentation revolution spread!

*But wait, you may be saying. This guy has a PhD from Harvard and he wants me to believe that the patterns he observes from just five different salami prove this crazy idea of American microbial terroir? Fair enough. This isn't a perfect scientific study (as if that wasn't obvious by the fact that it is being published in *Lucky Peach*). But it does provide some much-needed data to more clearly develop the notion of microbial terroir in America.*

There are two perfect experiments to conduct that would really settle this whole microbial-terroir thing. First, I could make a ton of salami in Boston, using my own recipe, and then send them off to all five producers I studied and have them age the salami using the exact same techniques they normally use. (Salami producers: I would love to come check out your salami microbes. Call me?)

The second-best approach would be to take the unique microbial ecosystems from each of these salami and inoculate them into my basic salami recipe. Call it a microbial transplant. This would tell me if the variations in the microbes from place to place are really driving the flavor differences that I observe. Every other variable—environment and length of aging—would be held constant.

I tried this experiment in my amateur salami-aging cave (closet). The quick, and perhaps not surprising, answer is that the flavor differences we noticed in the original salami carried over to the experimental salamis. The yeasty/Staphy salami (like the Utah salami) were more well-rounded and earthy in their flavor profiles. The salami that had more mold growth (like the Oregon salami) had a sharper, almost metallic, blue-cheese pungency. So even when the meat ingredients are the same, the different microbial communities on the outside of the salami created noticeable differences in flavors. Fun stuff. ♦

NEXT PAGE: (Top row) Circles shows colonies of bacteria. Different colors = different species. More circles = more bacteria; (Bottom row) Circles show yeasts (smooth circles) and molds (fuzzies).

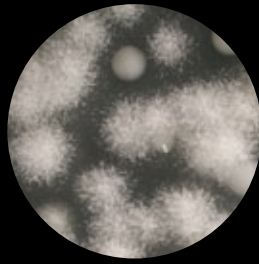




OLYMPIC PROVISIONS: The dream of microbes is alive in Portland.



OLLI: Light on mold (probably due to fake casing), but heavy on pork flavor.



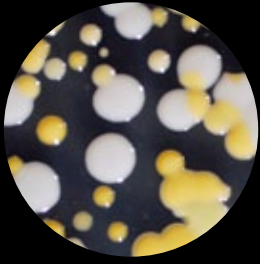
BOCCALONE: A mold-heavy salami (fuzz central) with few bacteria and mild flavor.



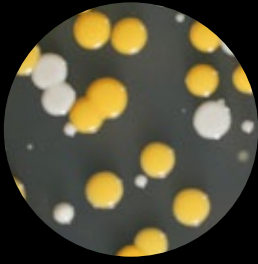
CREMINELLI: The yellow-gold crust of *Staphylococcus xylosus* is dreamy. Pure petrified porkiness.



FRA'MANI: Moist and yeasty, with the taste of rustic barnyard. It's like eating time.



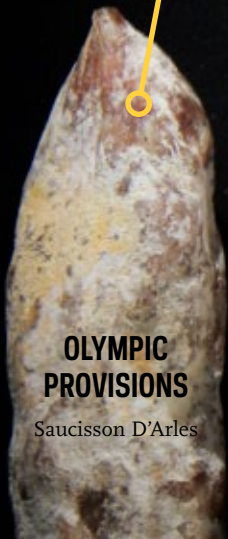
Olympic Provisions is wild, with as many as five different bacterial species, a yeast, and two molds. The diversity of microbes leads to the funkiness of flavors in this salami. This 20x-magnification view shows each bacterial species forming unique patches in this microbial landscape.



Here's what the rind of Boccalone's salami looks like at 20x magnification. Kind of boring to a microbiologist, with only one mold and one yeast. Boccalone's low-diversity rind matches the relatively mild flavor profile.



Orange-yellow crusts are a good sign of deliciousness. These crusts are formed by the bacterium *Staphylococcus xylosus*. The presence of this species is considered a sign of excellent aging conditions and potential for high concentration of typical salami flavors.



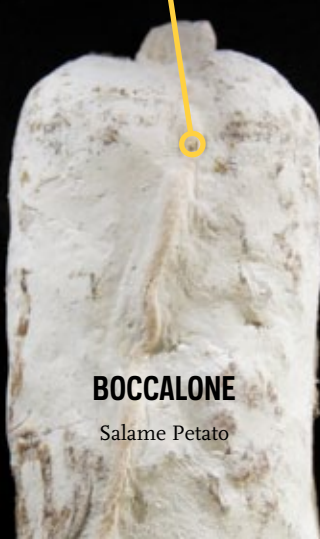
OLYMPIC PROVISIONS

Saucisson D'Arles



OLLI

Norcino Salame



BOCCALONE

Salame Petato



CREMINELLI

Casalingo



FRA'MANI

Salametto