Pickled Beer: Tandem Fermentation of Flemish Sour Ale

Raj B Apte
Matadero Creek Brewery

.

Background Reading

Battcock & Azam-Ali, Fermented Fruits and Vegetables, A Global Perspective

Introduction

Flemish Sour Ale is a group of drinks produced in Brussels and West Flanders. In 1864, Baudelaire, the French writer who had found asylum in Brussels, wrote that the people of Brussels drank their Faro twice: 'The Faro is being tapped from the big latrine, the Senne. This beverage is prepared from the excrements of the city, and so for centuries Brussels people have drunk their own urine.' Clearly these ales are for people who like their drink as ripe as their cheese.

This talk will present a discussion some of the basic principles of fermentation, and the example of how beer brewing and vegetable pickling are combined in making traditional Flemish Sour Ale demonstrates the basic principles of tandem fermentation. The essential points are these. The various microbes that ferment all have different requirements to prosper. Some fermentations by one microbe may produce conditions that a second finds hospitable. This can continue for two, three, four, or even five steps, as one set of microbes gives way to the next. This is part of the reason that fermented foods exhibit a fascinating complexity, as each successive fermentation adds a new layer of flavors. We will review the outlines of how this process works for beer, for pickling ,and finally for sour ale. At the end those who stay awake and ask good questions will get to taste.

Cast

The story of fermentation has actors, and they have names. I am going to use the proper scientific names for yeast and bacteria. Lets review them briefly so that they won't seem so strange. Think of it as the Dramatis Personae of Euripides—not familiar, but nothing you can't learn. There will be free beer for anyone who catches me mentioning microorganisms other than these five genera.

Saccharomyces: the genus of the common bakers and brewers yeast. This is what you buy in foil packets for baking bread. Saccharo—means sugar, myces mean mold. It makes nearly all the alcohol you drink.

Brettanomyces: a slow growing yeast that is common and unwanted in the winemaking and brewing industries. It is easy to control in stainless steel fermentation vessels, but impossible to remove from wood because it lives inside the pores and even steam will not kill it. Brettano means British, myces means mold.

Pediococcus: an acid-producing bacterium that finds its principle commercial use in preserving sausages. The acidity that causes us trouble when we overindulge in pepperoni pizza starts here. I don't know how this one got its name, but coccus is just a round bacterium.

Lactobacillus: another acid producing bacterium that makes our yoghurt and cheese. Generally avoided in brewing, but where the sour in sourdough comes from. Lacto-milk, bacillus-a rod

Acetobacter: you guessed it—this is the bug that converts sugar or alcohol into acetic acid—the sourness of vinegar. It was once a pest in the winemaking industry, but unlike all the other bugs we have talked about, this one needs oxygen to survive. Aceto-mean vinegar.

Fermentation

Fermentation is a collection of methods to make food more lasting, convenient, nutritious, digestible, or tasty. The unifying features are microbes, substrates, and environments.

Microbes used in fermentations include molds such as brewers yeast, Saccharomyces, and bacteria such as Pediococcus and Lactobacillus. Generally, each microbe has some things which it can or cannot digest and affects the environment to exclude its competitors.

The substrate is nothing more than all the nutrition available to the microbes. In this talk the sugars in grain will be the primary substrate. Other examples of substrates include the lactose in milk or the sugars and starches in cabbage. Some microbes can digest sugar and not starch, or vice versa. There are dozens of types of sugar molecules, and each species or variety has a characteristic pattern of abilities and disabilities. Thus one chooses the substrate and the microbe to obtain the desired product. For example, fall or winter cabbage has less sugar than the summer variety and produces a more nuanced product, I'm told. In the case of beer, one has a great deal of control over the mix of sugars and starches. More on that later.

Lastly we come to environment. This is twofold. First, some aspects of environment strongly control what can grow and how it grows. The classic example is oxygen—some bugs need oxygen to survive, some can survive with or without, and one, Pediococcus, is actually killed by oxygen. Other variables that the fermenter can control include moisture, temperature, salt, and acidity. Second, there are variables affected by the microbes themselves. Principle here are acidity and alcohol, both products that microbes produce as products of metabolism that can kill competing organisms.

Both acid and alcohol are strong preservatives. Anyone who cans knows that a high-acid foods like tomatoes and fruits are preserved by boiling water bath, but vegetables that are not acidic require pressure cooking for complete sterilization. This is because botulism is restrained by acid. Alcohol is even stronger a preservative. There are no known human pathogens capable of living in even light beer (3% alcohol). This is why the Romans added a small amount of wine to their water to sanitize it. In fact, it was both rude and illegal to consume wine straight, as we do now. At 7-15% alcohol a beverage gains aging capability and need fear nothing other than Acetobacter, which in the presence of oxygen can digest ethanol to acetic acid, vinegar. Above 20%, say brandy or whiskey, even the Acetobacter is killed, and the beverage is shelf stable. This is why once open your liquors are safe on the counter for months or years, your fortified wines for days to months, your wines days, and your beer only hours.

I’ll describe two simple fermentations: beer and sauerkraut. Then I’ll develop the theme of this talk, tandem fermentations. Tandem fermentations are when one microorganism transforms a substrate, and by so doing makes it possible for a second organism to take over. Each step transforms what was left from the previous. It is the layer of subsequent fermentation products and byproducts that give Flemish sour ale its character. But as you may have gathered from the background reading, tandem fermentations are extremely common—only modern fast-food processing has enabled single fermentations.

Now for the first step.

Making Beer

Making regular beer, including all the standard varieties of fresh ales and lagers, follows a standard set of procedures. You start with grain, water, yeast, and spices. Let me outline the process to help illuminate some of the general processes involved before we get into details. There are specialized terms here, good Anglo-Saxon ones.

Malting is the process of sprouting grains. Think of wheat germinating to wheat grass. When the grass just starts to emerge from the corn, its called malt. Barley is the most common malted grain.

Mashing is the process of heating water and malted grain to extract all the starch from the grain and convert some of it to sugar.

Wort is the yummy solution of malt sugars and starches produced by mashing. Basically its sugar water, and plays the same role as fruit juice that's made into wine or cider or milk that's made into buttermilk. It is the substrate for beer-making.

Now lets go through the process in more detail. Malting is the process of germinating grains. Typically barley is soaked and allowed to sprout. When the plantlets grow to a certain size, the barley plantlet is killed and dried. During the sprouting process, however, many changes occur within the grain. The most basic is that enzymes are generated that can break starch down into simple sugars. Starches are long chains of sugar molecules, and are stable unless these special enzymes are used to break them down. Why do they exist in the freshly germinated plant? Because the plant itself needs to convert the starch to sugar in order to use it to grow.

Rejuvelac is a pro-biotic beverage. It is made by taking the fresh malt and drowning it. The little plants fall apart and all their nutrients are released to the liquor. It ferments for a few days making a tiny amount of acid, alcohol, and bubbles. But its teaming with digestive microbes and is a very good way to rebuild the intestinal fauna. To make real beer, we use much less water and kiln or roast the malt before using it, but the bugs are the same. Kvass is another variant of grain-based fermented drinks.

To start the beer making process, dry barley malt is put in a large pot of warm water. The combination of dry barley grist and warm water is called the 'mash' and the process is called 'mashing'. The temperature is critical because there are two different enzymes, each with a different optimum temperature, and each of which break down starch into different types of sugars, which we'll call simple and complex. For Saccharomyces—the brewer's yeast-- the simple sugars are digestible and the complex are not. Of course, other yeasts and bacteria have different digestive abilities and some can eat the complex sugars, but these are kept out of lager breweries at all costs. One consumer of complex sugar is Pediococcus damnosus. Guess why its called that. Others are of the genus Lactobacillus. These are among the principle brewery demons.

Why produce both simple and complex sugars if the yeast can only eat the simple ones? In the case of normal beer, its because the complex sugars, which remain even after the beer is bottled, add a firmness and viscosity that contribute to the mouth feel of the beer. Without the complex sugars, beer feels and tastes watery. In our case the ability to independently control the sugar and starch content is essential to controlling how sour and earthy our pickled beer will get.

One noteworthy variant of the mashing process is spit beer. Human saliva contains the same enzymes as the malt. So if you don't know how to malt grain, you can still make the conversion to sugar by chewing on raw grain. Many of you will experience a sweetness if you hold a cracker in your mouth for a few minutes without swallowing. That's your salivary enzymes converting starch to sugar. The fact that we are designed to digest raw grain should not be surprising—that's what we did before brewers and bakers. Spit beer continues to be produced by some people.

Another variant is rice beer, also called rice wine. In this case a mold is used that infects a mass of wet rice. The mold produces enzymes which can subsequently be manipulated to convert all the rice starch to sugar. A Saccharomyces fermentation follows. This is our first example of tandem fermentations, in which one fermentation follows a second. The same mold is used to make tempeh.

Once the grain has steeped, and the starch has been converted to sugar, the grain is strained and discarded. The next step is to boil the wort. This does a number of complicated chemical things that make the beer better, but the obvious one is that it sterilizes it and concentrates it. Spices such as hops are added during the boil, as might sugar and honey. Spices might include orange peel and coriander (a typical Belgian addition); a gruit (which is a blend of spices controlled by the catholic church); ginger, sasparilla, licorice or birch root; or oddities such as cocoa powder or dried smoked chilies. When chilled, the wort is ready for fermentation.

Hops are the preferred spice used in beer for a simple reason—they are poisonous to bacteria. When boiled two important groups of chemicals are released. The first group of chemicals taste bitter and are the principle source of bitterness in beer. They bond to cellular machinery in bacteria and render the bacteria incapable of metabolizing or reproducing. They don't kill the bacteria, but they leave them bound and gagged and watching network television. Its not a pretty sight. These chemicals are nature's own preservatives. The second group of chemicals are anti-oxidants, which help preserve the beer from staling. That hops has these properties is not surprising: many spices are strongly anti-bacterial or anti-fungal. For example, cinnamon is commonly applied to flesh wounds of orchids to prevent fungal infection. Hops bitterness are particularly effective against Lactobacillus, a common brewery infection. When Lactobacillus gets into beer, it makes it sour, sometimes buttery, and sometime like overboiled cabbage. Without hops bitterness, beer can be quite sweet, even cloying. So the hops bitterness is used to balance the malty sweetness. Of course, hops also adds floral components that make beer smell good. What is truly remarkable about humans is that they can digest a variety of poisons from chocolate to alcohol to hops to cinnamon to salt to tobacco. Humans are remarkable omnivores. In last week's edition of Science, the best theory for extinction of the Neanderthals during the last ice age is because they could not adapt to the changing food supply. Modern man will pretty much eat anything but dry grass. Now back to our boiled wort.

Yeast is added and the unfermented sugary beer wort begins to ferment. If the fermentation is clean and only Saccharomyces brewers yeast is present, then the simple sugars are converted to alcohol and the complex sugars remain: to add body. The yeast, which have consumed all the protein and much of the wort nutrition, settle to the bottom of the fermenter and wait, hoping there will be food again someday. The beer is poured off and bottled or kegged. The leftover yeast is fed to pigs or Australians or the British, who salt it, and call it Vegemite or Marmite.

Now let me say a few words about a yeast that is very controversial in the winemaking and beermaking business: Brettanomyces. It's a yeast, but while Saccharomyces can covert a bucket of grapes to wine in a week, Brettanomyces is a very slow grower. In nature, it probably teams with other saprophytes—organisms that eat decaying plant material--to decompose cellulose. It can eat wood. In wine that is aged in wood, the Brettanomyces grows slowly, both in the wood and in the wine. But besides alcohol it produces some very distinct flavor compounds, variously described as mousy, fecal, urine, or barnyard. The latter term is used by proponents. Generally, in Bordeaux a slight Brettanomyces note is considered to give an earthiness that contrasts well with the fruitiness of the grapes. French toleration of measurable Brettanomyces and significant BO has never been correlated, but it is an avenue for future research. California winemakers regard all Brettanomyces as a fault. Brettanomyces adds the same challenges to wine that ripeness does to cheese.

In beer, Brettanomyces is also regarded as a flaw, but not in Belgium. There the Brettanomyces is used to add subtly a light earthiness, as in Bordeaux, or as a dominant flavor. I'll have much more to say about this shortly. In both the case of beer and wine, a Saccharomyces fermentation happens first, and Brettanomyces second. This is another example of a tandem ferment. If you get the chance, three great beers with subtle Brettanomyces effects are Orval, a trappist beer; Reinaert's Flemish Wild Ale, which is available at Plumpjack; and Biere de Mars, from New Belgium Brewing Co.

Pickling

Pickling is a process in which light brine is applied to a substrate to inhibit yeasts and allow acid-producing bacteria to eat the sugars and preserve the food. The bacteria involved form two groups, depending on what they poop. Lactic acid is a 'sweeter' acid that is the sourness in yoghurt, sauerkraut. Acetic acid has a stronger smell and is the sourness behind vinegar. Generally pickling using lactic bacteria requires fermentation of the food to be preserved. Pickling using acetic acid involves making wine first, then vinegar from the wine, and lastly dunking the food to be preserved into the vinegar. The food itself does not ferment.

Let's take sauerkraut as our example. Fresh cabbage is shredded, mixed with 1.5% salt, and packed in airtight containers. The best kraut is made in a container that has a water trap that allows CO2 to be expelled without allowing air back in—very much like the elbow trap underneath your kitchen sinks. All yeasts are inhibited by 1% salt solutions, about the level of salt in animal blood. But bacteria can cope with this salt level. In anaerobic, salty, moist conditions the bugs that grows happiest are Lactobacillus and Pediococcus. You will recognize them as the brewery contaminants above that are suppressed by good hygiene and bitterness in hops. In a nutshell, the shredded salted cabbage is kept warm (like 65F) for a few weeks and then kept cool for a few more. During the warm period the lactic bacteria eat all the simple sugars and starches present in the cabbage, but even they cannot digest cellulose. The increased acidity, lack of simple sugars, and salt give the sauerkraut its very long shelf life. As in brewing, fast-food people will pasteurize the kraut, but my preference is for unpasteurized.

Generally lactic fermentations produce up to 2.5% lactic acid. Lactic acid, like Lactobacillus, takes its name from milk, where the sugar called lactose is fermented by Lactobacillus into lactic acid. This process produces yoghurt, buttermilk, kefir, and sour cream. The lactic acid acts as a preservative. The difference between beer and sauerkraut is the salt, the presence of which lets the Lactobacillus work and suppresses the Saccharomyces.

Vinegar

The lactic bacteria, Lactobacillus and Pediococcus eat sugars and produce lactic acid. The acetic bacteria, eg Acetobacter, eat sugar or alcohol and produce acetic acid, but only in the presence of oxygen. Vinegar was traditionally made by inoculating wine with Acetobacter and allowing conversion to occur over a few weeks to months. The key differences between acetic and lactic bacteria are that acetic bacteria are more tolerant of alcohol; acetic acid bacteria are much more sensitive to salt; acetic bacteria are aerobic; and that acetic bacteria can produce 6-8% acetic acid, while lactic bacteria will kill themselves at 2% lactic acid. In winemaking acetic acid bacteria are considered a major nuisance—and acetic acid in wine is referred to as 'volatile acidity' and is considered a defect by nearly everyone. If you leave a bottle of wine open long enough with just a screen covering it, eventually Acetobacter will find it and give you vinegar. Making wine and then vinegar is another example of tandem fermentation.

If you take any vegetable and soak it in salt and acetic acid, as many people do with cucumbers, the vegetable will be preserved almost indefinitely. The salt inhibits the acetic bacteria, and the acetic acid inhibits everything else. Its not fermentation (that happened in making the vinegar when the sugar was converted to alcohol and when the alcohol was converted to acetic acid). Pickled cucumbers are made with either lactic or acetic methods.

Given that Acetobacter is killed by salt, its interesting to note that the Chinese have a very nice method of preserving their cooking wine. European cooks generally use freshly opened bottles of wine to cook with, or they use a fortified wine like sherry. As you recall, at 20% alcohol, the sherry is safe from Acetobacter, but requires a distillation to get the high alcohol. By adding 1% salt to the rice wine, Shao Xing may be preserved in the kitchen indefinitely. Since salt would have been added to the food anyway, nothing is lost. This method doesn't entirely work for red cooking wine because the oxygen in the air can damage the red wine chemically, even if its microbiologically stable. But white wines can be preserved for cooking with salt.

The best part of traditional Indian food is the pickled vegetables on the side. Indians will pickle mangoes, lemons, eggplant, garlic, and much else. They use a strong brine and lots of spices with low moisture. The result is a very weak lactic fermentation that renders food shelf stable. My mom often uses several cups of a mixture of equal parts salt, sugar, and cayenne pepper to preserve lemons.

I have covered the basics of all the processes needed to make Flemish sour ale, which amounts to an expansive review of fermentation in general, but it remains to put it all together. Lets take a break here and make sure everyone's questions thus far have been answered.

Flemish Sour Ale

Flemish Sour Ale is a style of beer made in Flanders that, while a small niche today, probably represents the bulk of European brewing from 1500 to 1800. It is 5-8% alcohol, sour and sweet, with little to no bitterness and hop aroma and a very complex bouquet. Related styles were common in Britain, Ireland, and the German League. Beer at that time consisted of three very different beverages. The cheap one was fresh ale, served within a week of brewing and from 2-6% alcohol. It was cheap because you don't use very much grain and you don't have to age it. The Czech invention, laagering, produced a very clean beer that aged in cold caves for a few months to smooth out. This invention took Europe by storm and is brewed throughout the world. These are 3-8% abv. Aged beer, a very expensive commodity, was 6-12% abv. The ale made by Jefferson was of this type. These were aged for 2 years and then served, and today are best represented by Flemish Sour ale at the less alcoholic end, and barleywines at the high end. At 6% alcohol many souring bugs can survive and during the two years aging can produce 0.5-2% acidity. At 10 or 12% alcohol the beer does not sour and has a graceful, dried fruit flavor. Aged beers are nearly extinct. By the time of the American revolution, hard cider was the common man's drink in this country. Madeira and aged beer were common but too expensive.

Early in the industrial revolution in England, Porter was invented. This beer was a blend of fresh ale and aged beer. The idea was that you could blend 1 part expensive aged beer and 4 parts cheap fresh beer and get something that had the best of both worlds. Most things called Porter today are not really Porters at all but just dark beers, but Guinness and Flemish sour ale are the real thing. Guinness keeps its secrets, but its no more than a few percent aged beer. Rodenbach, a sour ale from West Flanders, is more like 20%, as is one of the beers we'll try today. The other beer for today is pure aged beer. It will be the most strange to you. Many have asked Guinness for a taste of their unblended aged beer, but none have tasted and told.

Flemish ale is sour. This is your first clue that it is produced by a tandem fermentation: alcohol and acid. In fact, a whole host of beasts take their turn in developing the flavor, one after the other.

To start, Flemish ale is produced from a more-or-less unremarkable wort. It may be pale, but tends to be brown. Sometimes some wheat is used to round out the flavor. The first hint in the brewing process that something odd is going on happens at the boil. Normally, brewers are fastidious in choosing very fresh, very floral or citrus hops. But in a sour ale we don't want to inhibit the lactic bacteria with hops bitterness, and anyway bitterness and sourness are hard to take together. So hops are aged for a year or more, until they have very little bitterness left and no flavor. Why use them at all? And why so much—a typical Flemish ale uses twice the hops of a normal ale. The answer does not lie in what is lost during the aging—aroma and bitterness—but in what remains: anti-oxidants. This class of anti-oxidants survives the hop aging and enters the wort during boiling. Flemish ale is aged for two years before bottling, and sometimes the bottles are further aged by the consumer. During this time danger of oxidation of the beer's flavor is minimized by the hops. Tannins are related chemicals and play the same role in red wine barrel aging.

The first fermentation of Flemish Sour Ale is by Saccharomyces and is a typical beer fermentation to 5-7% alcohol. But then a second lactic acid fermentation by Lactobacillus continues from the second to the eighteenth week. A third fermentation that produces more lactic acid and alcohol follows by Pediococcus and Brettanomyces. Then a fourth fermentation by Brettanomyces and Acetobacter produces acetic acid. These four fermentations take a year to complete. After a second summer of aging, the aged beer is ready for bottling. Now lets look at each step in a bit more detail.

The most traditional Flemish sour ales are Geuze and Kriek. Both of these ales are spontaneously fermented, which means that no yeast is added by the brewer. But in fact every surface of the brewery is covered with yeast as are all the fermentation and storage barrels. While many people like the idea that Geuze can only be produced in Peyottenland because that is where the right yeast live, the truth is that Brettanomyces was first isolated from English ale and is present in wineries throughout the world. So its possible to inoculate Flemish sour ales using test tubes of sterile-cultured microorganisms, one after the other, to rely on the brewery environment itself.

The second lactic fermentation is the staling process that most brewers seek to avoid by heavy hopping. When the British first built their empire, the shipped beer all the way from Britain to their new colonies. To protect against this secondary fermentation, they hopped the beer strongly. This is the origin of IPA, India Pale Ale. At the time, the brewer was seeking the sweet taste of a fresh ale, despite the six month ship-board aging. With aged hops, the Flemish ale readily undergoes lactic fermentation.

The third Pediococcus\Brettanomyces fermentation is rather interesting. Both bugs are careful, slow, and very secretive. They can live in the wood used to age the barrels and are never explicitly added to the brew: they simply persist in the barrel from batch to batch. This fermentation takes half a year. What do the bugs eat? All the simple sugars were eaten by the Saccharomyces and the few that it had trouble with were eaten by the Lactobacillus. The Pediococcus can produce enzymes to convert the complex sugars in the wort to sugar. The enzyme floats about in the free wort, slowly turning complex sugars to simple sugars. The Pediococcus has done this to feed itself, but the Brettanomyces goes along for the ride. While the Pediococcus produces the acidity the Brettanomyces produces the earthiness. Why does this stop at the end of the year? Not because the complex sugars have run out, but the wort has became so acidic that the Pediococcus dies and with it the source of the enzyme, which soon decays. Also, the Brettanomyces (and any residual Saccharomyces) have been eating up any oxygen that diffuses into the fermentation vessel, typically a large wooden tun. But as the yeast die out, the oxygen level increases, and Pediococcus finds oxygen toxic.

Left to itself and with a definite but decreasing supply of enzyme and with rising oxygen levels, the Brettanomyces bravely marches on and is joined by Acetobacter. The former digests what sugars it can and produces alcohol or acetic acid, depending upon whether there in oxygen present. The latter eats alcohol and produces acetic acid. As the enzyme supply fails, the Brettanomyces starve to death, leaving only Acetobacter. It would happily turn everything to malt vinegar if given lots of oxygen, time, and warmth. But by now the ale is two years old and is ready for bottling.

The second diagram shows another fermentation at the same brewery started at the same time. The point is that two identical fermentations can travel through different paths and end up with different levels of lactic and acetic acids, earthiness, and alcohol levels.

Red wine fermentation provides an interesting glimpse at the generality of tandem fermentation. Often wines are made with lots of sulfites and chemical controls—particularly by Davis grads. But Europeans may allow natural fermentation to occur. This process then allows a succession of beasts to develop, just as in Flemish Sour Ale. It is this complexity that makes Flemish Sour Ale comparable to wine. Actually its more-so. In wine one seeks a balance between the grape aroma and the fermentation bouquet. The Flemish Sour Ale is all bouquet. Two years after brewing, the Ale is far from its cereal origins

Tasting

New Belgium Brewing Company is based in Ft Collins Colorado. A few years ago the largest maker of Flemish Sour Ale, Rodenbach, was bought over by a bland, large conglomerate. So the head brewer went looking for a new home. He ended up in Colorado as one of a handful of Belgian brewers in the US. Belgium occupies a unique space in the brewing world. It's a small country, but accounts for half of the beer styles in the world. From that tradition, but mindful of the need to introduce new things carefully, NBB has been transforming the usual microbrewery fare into a series of wonderful new tastes. The beers we have been provided tonight are both sour ales, from the most experimental end of NBBs product line.

Transatlantique Kriek is a blended beer. A traditional sour ale is made by one of the most prestigious Belgian brewers, Frank Boon. He dumps a load of cherries in it after the first year's fermentation. After more aging, the ale is blended in Colorado with a golden ale to soften the taste and allow more subtlety to come through.

La Folie is made entirely in Colorado. It's a traditional Flemish sour ale, with no softening or blending, although different casks are blended to obtain a uniform flavor. Because these are new to most of you, taste slowly and carefully. Some people will always dislike the sourness or the earthiness. But you never know. Remember your first experience with mold-ripened chase.