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Yeast and Other Fermentation Agents

Yeast Makes Beer

It is said that brewers make wort, but yeast makes beer. The real magic of beer making happens in the fermentation tanks. Until Louis Pasteur isolated yeast in the mid 19th century, the process of fermentation was not understood. Early household breweries had a "magic stick", which when used to stir the wort, would start the miraculous process. Clearly that stick harbored the household yeast that turned the wort into beer. Among the English the mysterious source of fermentation was called "godisgood." The Bavarian Reinheitsgebot (Purity Laws) of 1516 did not include yeast among the allowable beer ingredients and had to be revised following its discovery.

Thanks to Pasteur, brewers today have detailed knowledge of the fermentation process. The affects of temperature, cell-count, yeast health, and fermenter geometry are all well understood and manipulated by brewers to achieve specific results. Hundreds if not thousands of yeast strains, originally nurtured through centuries of repeated re-use in particular breweries, have now been laboratory cultured and made available to brewers everywhere. These strains are known to produce reasonably predictable results time after time. The affects of fermentation on the final flavor, aroma, and mouthfeel of beer cannot be understated. If a brewer changes yeast strain, they have created a different beer.

Fermentation

What is Fermentation?

Fermentation is defined as any of a group of chemical reactions that split complex organic compounds into relatively simple substances. In beer the most common form of fermentation is the *anaerobic* (oxygen-free) conversion of sugar to carbon dioxide and ethyl alcohol by yeast. Stated more simply, yeast cells consume and metabolize sugars in the wort and excrete CO_2 and alcohol. During fermentation other chemical by-products are produced that are critical to flavor and aroma. These include *phenols*, *esters*, and *acids*. While anaerobic fermentation by yeast is the most common form in the production of beer, other agents, including "wild" yeasts and bacteria, are sometimes used, some of which work *aerobically*.

The degree to which the sugars are consumed during fermentation is called *attenuation*. The percentage of attenuation is determined by comparing the *specific gravity* of the wort at the start and finish of fermentation. Specific gravity is a measurement of the amount of available sugar made by comparing the density of the wort to that of pure water. A beer with an *original gravity* of 1.040 that ferments to a *final gravity* of 1.010 it would have an apparent attenuation of 75%. Another way of measuring the wort density and sugar content is in *degrees Plato*. This is a measurement of the degree to which light rays are bent as they pass through a liquid. A beer with an original gravity of 1.040 on the specific gravity scale would be at 10° Plato. Higher levels of attenuation lead to lighter, drier beers while lower attenuation produces beers with fuller body and sweeter finishes.

Stages of Fermentation

Yeast fermentation proceeds in three phases. During each phase the yeast have different needs and perform different functions en route to making beer.

- *Adaptive or Lag Phase* – The lag phase begins immediately after yeast is pitched into the wort and lasts about twenty-four hours. During this phase the yeast are assessing their new environment, taking stock of the available sugars, oxygen, and other nutrients, and developing the enzymes needed to adapt. It is also a period of rapid reproduction. Yeast reproduces asexually by splitting off daughter cells, or *budding*. For this to occur, the cells need to develop strong cell walls. While this can be accomplished anaerobically, it is done more efficiently in the presence of oxygen. For this reason brewers *aerate* the wort on the way to the fermenter. Once the available oxygen has been used up, yeast switches metabolic pathways and begins anaerobic fermentation.

- *Attenuative Phase* – The attenuative phase lasts from three to ten days depending on the type and health of the yeast. During the attenuative phase, yeast is vigorously converting sugar to CO_2, alcohol, and other by-products. A thick, bubbly, foam of yeast, proteins, hop resins, and trapped CO_2 called *kreusen* forms on top of the fermenting beer. As the available sugars are consumed and the alcohol level rises, the yeast begins to settle out and the head of kreusen drops, signaling the end of this phase.

- *Conditioning Phase* – After primary fermentation is complete, most of the yeast goes dormant. The still-active yeast now set about the task of cleaning up. The simple sugars consumed, yeast metabolizes more complex sugars and re-absorbs undesirable compounds excreted during the early stages of fermentation. These tasks completed, the yeast forms clumps, a process called *flocculation*, and drops to the bottom of the fermenter. The conditioning phase may last a week for ales and up to several months for lagers. Lagers, and sometimes ales, are cold conditioned at temperatures near freezing, causing more yeast to drop out of suspension for a brighter beer.

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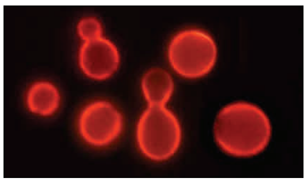
Yeast

What is Yeast?

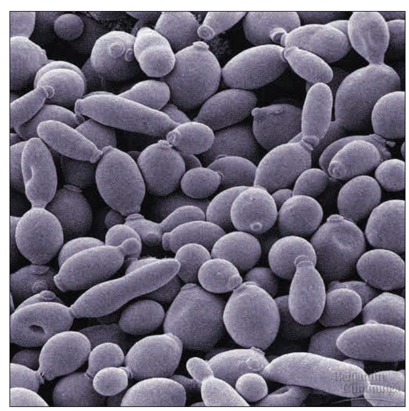


Brewer's yeast (*Saccharomyces cerevisiae*) is a member of the kingdom Fungi. Perhaps one of the earliest domesticated organisms, it has been used for fermentation and baking going back thousands of years. Yeast is unique among living things in that it can grow and reproduce both with and without oxygen. As described above, it survives without oxygen by converting sugars into CO_2 and alcohol, the process we call fermentation. Yeast reproduces asexually by budding, the splitting off daughter cells.

Yeast Types

There are two main types of yeast used in brewing, top-fermenting ale yeast and bottom-fermenting lager yeast. These yeast types are so named because of their tendency to form clumps or flocculate near the top or the bottom of the fermenter before dropping out of solution at the end of fermentation. Each of these types has different characteristics that affect the flavor, aroma, and mouthfeel of the finished beer.

- *Ale Yeast (Saccharomyces cerevisiae)* – Top-fermenting ale yeast prefer warm temperature fermentations between 65° and 75° Fahrenheit. At lower temperatures they will slow down and ultimately go dormant. These warmer fermentation temperatures promote the creation of fermentation by-products that greatly affect the flavor and aroma of beer. The primary of these by-products are *esters* that give beer fruity flavors and *phenols* that give spicy flavors. In higher gravity beers the high fermentation temperatures can also cause yeast to create *fusil alcohols* that give unwanted solvent notes. Ale yeast also leaves behind some longer chain sugars that lager yeast will ferment, resulting in beers with a fuller and rounder mouthfeel.



- *Lager Yeast (Saccharomyces pastorianus)* – Bottom-fermenting lager yeast was first isolated at the Carlsberg Laboratory in Denmark. It is a hybrid of *S. cerevisiae* with another yeast *S. bayanus*. This hybridization probably occurred in the 16^{th} century as yeast adapted to cold conditioning in German lagering caves. Lager yeasts ferment at lower temperatures between 45° and 55° Fahrenheit. Lager yeasts are able to ferment certain long-chain sugars that ale yeast cannot. This gives lager beers a lighter, crisper mouthfeel. Also, low temperature fermentation inhibits the production of esters and phenols, giving the beers a clean profile without yeast derived fruit and spice notes. Lager yeasts ferment more slowly and require a long conditioning period at temperatures near freezing.

Yeast Strains

While there are only two species of brewer's yeast, there are hundreds, if not thousands of yeast strains, each one providing a different flavor profile to beer. These strains are mutations that developed in response to the brewing conditions and beer styles made at particular breweries. Yeast is so sensitive to local conditions that two breweries can use the same yeast strain, but will produce beers with different yeast profiles. For example, many of the Trappist breweries in Belgium use yeast from the Westmalle brewery. The character that each one gets from that yeast varies widely. While this is true, certain broad generalizations can be made about geographical families of strains.

- *English Yeasts* – English yeasts have developed to leave a malt forward profile with high levels of fruity esters. Some strains leave behind another fermentation by-product call *diacetyl* that, in small amounts, gives beer a slight buttery or butterscotch character. In large amounts diacetyl is considered a flaw.

- *Belgian Yeasts* – The unique profile of Belgian yeast strains is the defining characteristic of Belgian beers. These yeasts produce beers with a particular combination of banana and cherry flavored esters with black pepper phenols that I describe as "cotton candy-like."

- *German Wheat Yeasts* – Once again the ester and phenol profile of these beers defines the style. Strong banana and clove character that comes together as "bubble gum" or "Circus Peanut Candy" is the hallmark of these strains. These are *low flocculating* yeasts, meaning that they stay suspended in the beer, giving it a cloudy appearance.

- *American Ale Yeasts* – American ale yeasts are known for their clean, low ester and phenol profiles. When fermented at the low end of their temperature range they can be used to create lager-like beers.

Other Fermentation Agents

Bring on the Funk

While brewer's yeast is the most common fermentation agent for beer, certain traditional styles and some new experimental styles depend on "wild" yeasts and bacteria to do at least part of the job. Belgium has a long tradition of *spontaneously fermented* beers in which cooling wort is exposed to the air, inoculating it with the local micro-flora. Spontaneously fermented beers are also now being made by adventurous craft brewers in Sonoma County, California and Portland, Maine. In addition, many breweries have barrel-aging programs in which traditionally fermented beers are aged in barrels that house a variety of wild yeasts and bacteria. These beers are some of the most unique and complex in the world.

While there may be hundreds of wild agents at work in the creation of these beers, there are a few standards that are available to brewers in pure, cultured forms.

- *Brettanomyces* – While not technically "wild", *Brettanomyces* is often called "wild." It is commonly found on fruit skin. There are three strains of Brettanomyces available to brewers from commercial yeast banks, including *B. bruxellensis*, *B. claussenii*, *B. lambicus*, each producing somewhat different flavor profiles. Brettanomyces is commonly associated with high levels of fruitiness, giving cherry and pineapple notes. It is also an acid producer, leading to low levels of sourness. The most common flavors associated with Brettanomyces include barnyard, horse-blanket, and leather. Brettanomyces is used both in conjunction with brewer's yeast and as a sole fermentation agent.

- *Acetobacter* – *Acetobacter* is an acetic acid producing bacteria that converts sugar to alcohol through aerobic metabolism. It is the same bacteria used to make vinegar and imparts a sharp, vinegar-like sourness to beer. When combined with malt flavors it results in something resembling balsamic vinegar.

- *Lactic Acid Bacteria* – *Lactobacillus* and *pediococcus* are lactic acid producing bacteria that are important to the flavor profile of Belgian sour beers. These bacteria convert sugars to lactic acid through anaerobic fermentation. These result in tart flavors that more closely resemble the sourness of yogurt.

Vocabulary

Aerate – To mix air into solution to provide oxygen for yeast. Brewers must aerate wort prior to fermentation for healthy yeast growth.
Aerobic – A process that takes place in the presence of oxygen.
Anaerobic – A process that takes place in the absence of oxygen or may require its absence.
Attenuation – The degree of conversion of sugar to alcohol and CO_2.
Bottom Fermenting – A reference to the tendency of yeast to flocculate at the bottom of the fermenter at the end of fermentation. Usually refers to lager yeasts.
Budding – The asexual means of reproduction by yeast in which "daughter" cells split off from the original cell.
Degrees Plato – An alternative scale to measure the amount of sugar in wort by determining the amount of refraction of light passing through it. A specific gravity of 1.040 equals 10° Plato.
Esters – Aromatic compounds formed form alcohols by yeast action. Typically fruity.
Final Gravity (FG) – A measurement of the remaining sugar content/density of beer following fermentation.
Flocculation – The state of being clumped together. For yeast the clumping and settling out of solution after fermentation has completed.
Kreusen – Foamy head of yeast, proteins, and hop resins that forms on beer during peak fermentation.

Original Gravity (OG) – A measurement of the sugar content/density of wort prior to fermentation.
Phenols – A group of compounds consisting of a hydroxyl group (-OH) attached to an aromatic hydrocarbon that have various spicy, medicinal, or plastic flavors.
Pitching – The term for adding yeast to wort.
Specific Gravity (SG) – A measure of the malt sugar concentration/density of wort or beer. The specific gravity of water is 1.000 at 59° F. Typical original gravities for beer fall between 1.035 and 1.060.
Spontaneous Fermentation – Fermentation that is initiated by exposing wort to naturally occurring organisms either in the air or in wooden barrels.
Top Fermenting – A reference to the tendency of yeast to flocculate at the top of the fermenter at the end of fermentation. Usually refers to ale yeasts.