Fermentation Time Line

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What is yeast doing during beer fermentation? It is consuming wort sugars, and turning that sugar into new yeast cells, ethanol, CO_2, and flavor compounds. Brewers are primarily concerned about flavor compounds. In order to maximize the correct flavor compounds, it is helpful to know how yeast ferments beer.

Ale fermentation of brewers wort follows three phases: lag phase for 3-15 hours, exponential growth phase for 1-4 days, and stationary phase of yeast growth for 3-10 days. Each of these phases will be described in terms of yeast behavior.

Lag phase, 3-15 hours after pitching yeast:

When yeast is pitched into beer, it begins a process of acclimation to the environment. This is known as the "lag" phase. Yeast begin to uptake minerals and amino acids (nitrogen) from wort. Amino acids are used to build proteins. The amino acids that yeast can not obtain or get fast enough from wort need to manufactured by the yeast. Much the same way that humans need 100% of essential vitamins and minerals to make it though the day, yeast cells also need 100% of their vitamins and minerals (nutrients) to make it though a fermentation properly nourished.

All-malt wort is an excellent source of nitrogen, minerals, and vitamins. Most of the vitamins yeast need for proper fermentation are supplied in wort. Some examples of necessary vitamins are riboflavin, insositol, and biotin. Important minerals are phosphorous, sulphur, copper, iron, zinc, potassium, and sodium. As the minerals and vitamins are taken up from wort, yeast begins to manufacture enzymes necessary for growth. Wort can be supplemented with additional minerals and vitamins by using commercially available yeast nutrients, which will improve the health and performance of yeast.

Oxygen is rapidly absorbed from the wort during the lag phase. The yeast need this oxygen to grow in order to produce important cell wall constituents. It is important to provide enough oxygen into wort at the beginning of fermentation. By shaking the fermentor, a homebrewer is able to, at best, add about half the recommended level of 10 ppm oxygen into solution. This will produce satisfactory fermentation results, but to make sure a healthy fermentation will take place, oxygen can be added to the fermentor with several commercially available systems.

The lag phase can be carried out at a higher temperature than the rest of fermentation because very little flavor compounds are produced. Ethanol production is also very limited, therefore ester formation is not a concern. Some brewers begin the lag phase for ales at 72-75^{0}F, and complete the fermentation at 68^{0}F. This can be done with success for lagers too, with starting the lag phase at 72-75^{0}F and lowering the fermentation temperature to 50-55^{0}F.

Brewers will not see any visible activity during the lag phase, hence the way it got its name. But this phase is very important in building new healthy cells that will be able to complete fermentation. If the wort is overpitched, this will decrease the lag phase, and each individual cell will not be as healthy at the end of fermentation. Although it may feel reassuring to a homebrewer to see fermentation activity within one hour of pitching yeast, it is not best for the yeast.

Exponential growth phase: 1-4 days:

As the yeast comes out of lag phase, it starts to consume the sugars in solution. CO_2 is produced, which starts to expel from the airlock and create of surface layer of foam on the beer. The exponential, or logarithmic, phase of yeast growth is now starting. During this phase, the cell count will increase rapidly, and ethanol and flavor compounds will be produced. Airlocks will bubble like crazy within this time

frame. The aroma that escapes from the airlock of most neutral ale yeast fermentations has an "olive" smell.

The exponential phase occurs because yeast rapidly consume sugar. Wort sugar is consumed by yeast in a certain pattern. Glucose is used first, then fructose and sucrose. These are simple sugars, and can be quickly shuttled into metabolism. The glucose concentration in wort is roughly 14% of wort sugars.

Maltose is the centerpiece sugar of malt, and is a very important flavor component. It makes up 59% of wort sugars, and its use by yeast gives beer its characteristic flavors. There are 1 to 5 genes in yeast DNA that "turn on" in response to maltose, allowing for fermentation by brewers yeast. After maltose enters the cell through a special uptake mechanism, it is hydrolysed into glucose units by maltase enzymes. Glucose can then enter the normal metabolism cycle.

Maltotriose is fermented last. This is a tricky sugar for yeast to digest, and some yeast ferment maltotriose better then others. Some strains of brewers yeast do not ferment maltotriose at all! The more flocculent a yeast strain, the less maltotriose they tend to ferment. The ability to ferment maltotriose gives each strain its characteristic attenuation range.

At the height of activity, the beer is said to be at "high krausen". The head of foam on top of the fermentation turns yellow to brown. The colors stem primarily from precipitated malt and hop components. Brown spots form from oxidized hop resins.

Stationary phase of yeast growth- 3-10 days:

At this point, yeast growth slows down, and yeast enter into a stationary phase of growth. Most of the flavor and aroma compounds have been produced, which include fusel alcohols, esters, and sulfur compounds. The beer is called "green beer" because it does not yet have the acceptable balance of flavors.

Beer is matured in the stationary phase of growth, also known as the conditioning phase. Yeast reabsorb diacytyl that was produced during fermentation, and hydrogen sulphide escapes from the top of the fermentor as a gas. The krausen falls, and yeast begin to settle out, or "flocculate". It is important to check the degree of attenuation at this point to confirm that the yeast has completed fermentation. Some strains of yeast will begin to flocculate out before terminal gravity has been reached, and need to be "roused" back into solution.

Professional breweries will cool the contents of the fermentor gradually to 35-40^{0}F, which will force most of the yeast to flocculate. Most homebrewers do not have the facilities to do this, so they must wait for the fermentor to "clear". If the homebrew is to be bottled, flocculation can be allowed to complete in the bottles.

The three phases of yeast fermentation are lag phase, exponential growth phase, and stationary phase. By knowing what is going on in the fermentor during these phases, a homebrewer will be more comfortable with the fermentation and able to identify trouble areas.

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