Diacetyl Time Line

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Yeast is an amazing organism. It is responsible for producing bread, wine, distilled beverages, and ….beer! When yeast ferments beer, it produces over 500 different compounds. Many of these compounds give beer it's characteristic flavor and aroma. One of these compounds, although usually considered undesirable, is diacetyl.

Diacetyl gives a buttery, butterscotch-like flavor to beer. The flavor threshold of diacetyl is 0.1 parts per million (ppm) in "light" beer. Homebrewed beer can have levels from .05 to greater then 1.0 ppm. Factors that influence the diacetyl level in beer are fermentation temperature, aeration level, bacterial contamination, and the yeast strain used. This article will explain how diacetyl is formed and how the levels vary during the course of fermentation and maturation. (Fig. 1)

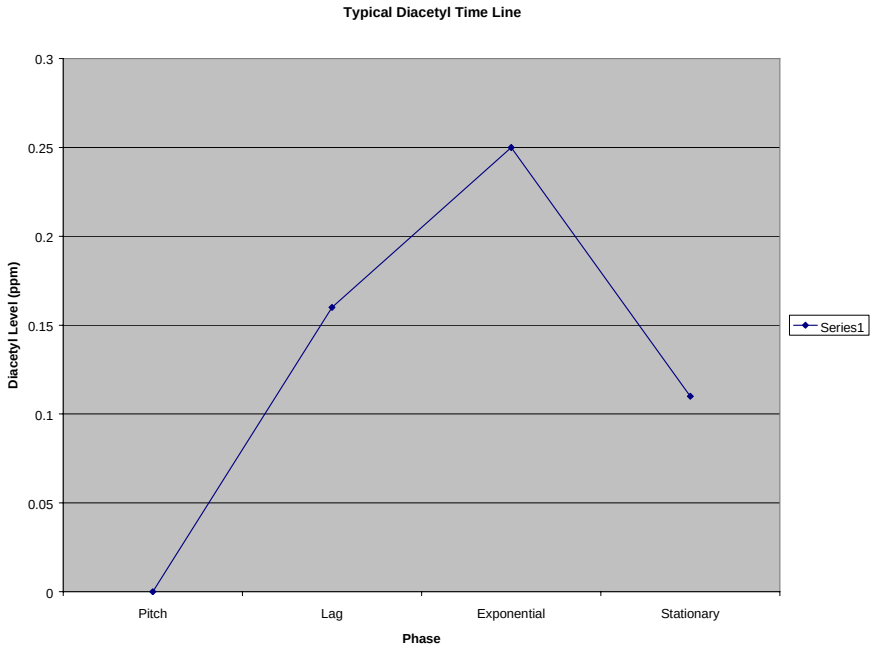

Fig. 1

Diacetyl is a small organic compound (Fig. 2), belonging to the chemical group called ketones. Another ketone commonly found in beer is 2,3-pentanedione. When the diacetyl level is checked in beer, 2,3-pentanedione is so similar that its level comes out in the test and the combined result is called the VDK (vicinal diketone) level.

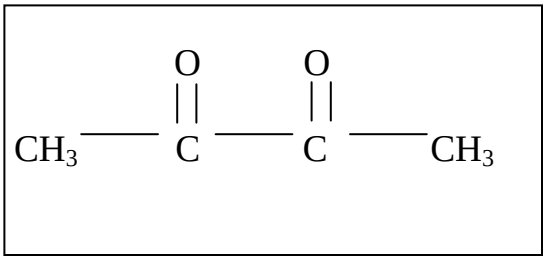

Fig 2: Diacetyl

After yeast is pitched into beer, the yeast undergo a lag phase, followed by a phase of very rapid growth called the exponential growth phase. During both the lag and exponential phase, yeast build amino acids, proteins, and other cell components. Most of these components do not make the flavor of the beer, but the various pathways produce individual compounds that leak out of the cell to effect beer flavor. One of the amino acids produced by yeast is valine. An intermediate compound in valine production is acetolactate (Fig. 3). Not all of the acetolactate produced eventually becomes valine, some will leak out of the cell and into the beer. This acetolactate is then chemically (not enzymaticly) converted to diacetyl in the beer. The chemical reaction is an oxidation, and high fermentation temperatures favor this reaction. Other factors that will increase diacetyl production in this phase are insufficient nutrients (i.e. the amino acid valine), which forces yeast to manufacture their own. For example, the more valine yeast produce, the more acetolacate intermediate is required, and hence the more diacetyl made. There is a strain specific phenomena here, because given the same conditions, different strains will produce different levels of diacetyl.

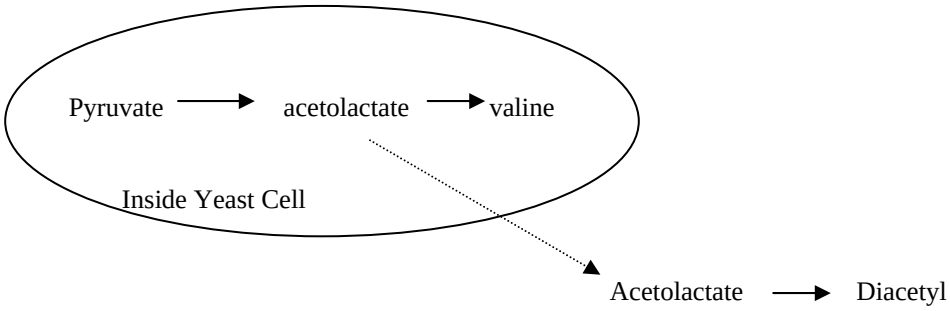

Fig.3

As yeast slow down in fermentation, they enter what is known as the stationary phase. This phase is where beer undergoes a maturation process to develop the correct balance of flavors. One of the key elements of maturation is diacetyl reduction. Not only do yeast produce the precursor to diacetyl, they also consume the diacetyl produced, and enzymaticly reduce it. Yeast reabsorb diacetyl and convert it to acetoin and subsequently to 2,3-butanediol (Fig.4).

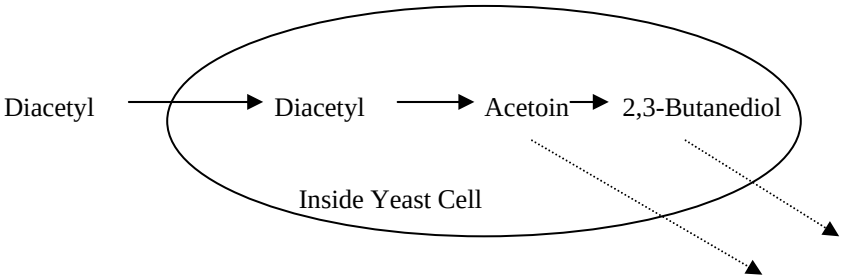

Fig. 4

Both acetoin and 2,3-butanediol can escape the cell, but neither contribute much in terms of flavor given their high flavor threshold.

It is important to provide sufficient maturation time for diacetyl reduction, commonly known as a "diacetyl rest". Diacetyl reduction is slower at colder temperatures, so it is essential to incorporate the diacetyl rest when making cold fermented lagers. The process is simply to raise the fermentation temperature from lager temperatures (50-55F) to 65-68F for a two day period near the close of the fermentation. Usually the diacetyl rest is begun when the beer is 2 to 5 specific gravity points away from the target terminal gravity. The temperature is then lowered to conditioning temperature following diacetyl reduction. For ale production, the fermentation temperature is usually 65-70F, so temperature modification is not necessary. But the fermentation should still be "rested" at this temperature for two days to ensure proper diacetyl reduction. Many brewers make the mistake to quickly crash the fermentation temperature following terminal gravity. Why not? The beer is done, people are thirsty, and there is no taste of diacetyl in the beer. Even though the diacetyl can't be tasted, however, the beer may contain high levels of the precursor, acetolactate, which can be converted to diacetyl. Once the yeast is removed, there is no way to get rid of the diacetyl.

There is another way to get the buttery, diacetyl flavor in beer. This is the diacetyl contribution that brewers would rather not talk about. You guessed it …..*contamination*. Lactic acid bacteria, *Pediococcus* and *Lactobacillus,* both produce diacetyl. These bacteria have historically been notorious contaminators of beer, and are called beer spoilers. They are anaerobic, alcohol and heat tolerant. This makes them happy to live in beer. The diacetyl produced by bacteria is far from pleasant, and can taste like sour butter. Small breweries and homebrewers have a difficult time bottling beer in a manner which eliminates lactic acid bacteria. This is one reason why great tasting beer can be bottled, only to develop pressure, sourness, and diacetyl flavors in as little as 8 weeks. What can be done? Sanitize well, bottle carefully and leave some yeast in suspension. This yeast won't kill bacteria, but it will reduce any diacetyl produced from oxidation of acetolactate in the bottle.

Most brewers do not like the presence of diacetyl in their beer because it is a hint of a possible fermentation or contamination problem. But some brewers desire their beer to contain diacetyl in the final product. For example, Red Hook ESB has a characteristic diacetyl taste. This is most likely produced from their yeast strain used or from the fermentation profile they employ. Some yeast strains, particularly flocculent English ale strains, are known to be heavy diacetyl producers. Alternatively, the fermentation temperature can be crashed following terminal gravity, which would prevent the diacetyl rest from taking place. Low levels of diacetyl produced in this manner can be pleasant, and many classic beer styles allow for low levels of diacetyl to be tasted in the beer.

In summary, diacetyl is formed by both yeast and bacteria. If a brewer can eliminate bacterial contamination, diacetyl levels can be controlled by choosing a particular yeast strain and by fermentation conditions. Fermentation parameters that effect diacetyl levels are temperature and aeration. High

fermentation temperatures promote diacetyl production, and low aeration levels when yeast is pitched will produce less healthy yeast, which are prone to higher diacetyl production. Ale fermentations will produce more diacetyl because they are fermented warmer than lagers, but the reduction will happen much quicker. Lager fermentations need to be given a "diacetyl rest" by increasing the fermentation temperature just before completing fermentation. A hydrometer should be used to measure the specific gravity to calculate when to start the diacetyl rest. The fermentation should never be rushed. Give the beer ample time for maturation, sanitize well, and make great beer!