TOPIC: PRODUCT INNOVATION, QUALITY

HOP CREEP: CAUSES AND REMEDIES

10 min read

Biological stability in beer is important to brewers. Beers that undergo a renewed fermentation may exhibit off flavors or aromas. In packaged beers, the extra carbon dioxide produced will be trapped in the vessel, leading to the beer being over carbonated. Dry hopping increases the intensity of hop aromas in a beer, but it sometimes has unwanted effects. Recently, it has been reported that dry hopping sometimes results in renewed fermentation. The reason for the dry hop spurred renewed fermentation has been recently discovered — although brewers have been aware of the phenomena since the 1890s.

Dry hopping is adding hops (*Humulus lupulus*) to beer after the boil and after or near the end of primary fermentation. Whole hops, pellet hops, Cryo hops, or hop extracts may be used for dry hopping. The aromatic oils in hops — including humulene, myrcene, and caryophyllene — are soluble and readily dissolve in beer. And, unlike with hops added to boiling wort, these volatile compounds are not lost to evaporation when a beer is dry hopped. Dry hopping adds hop aroma to beer; however, because the hops are not boiled, it does not add bitterness. Most modern IPAs are dry hopped and this technique has been around since at least the 18th Century. In the past, dry hopping was also believed to have preservative qualities in beer.

However, in some instances, dry hopping can also lead to a renewed fermentation. This renewed fermentation reduces the level of carbohydrates present in the beer, leads to more alcohol production, and produces carbon dioxide (CO_2). If the beer is already packaged, the resulting over carbonation can lead to gushing or — in extreme cases — a rupture of the vessel holding the beer. A renewed fermentation brought on by dry hopping can also cause diacetyl to form. With fewer yeast cells in suspension compared to during primary fermentation, this diacetyl will only slowly be neutralized by the yeast. This can result in increased cellaring time and tie up tanks, which negatively affects overall brewery capacity. This phenomenon has come to be called hop creep.

The brewers at Allagash were the first to bring this to the attention of modern brewers. In 2016, when making their first dry hopped beer, they noted that the attenuation was much higher than expected and the beer overshot their carbonation target. It ended up at 4.5 volumes of CO_2, when they were aiming for 3.0. In a like manner, the alcohol content was out of spec on the high side. So, they set out to discover what was going on. An examination of the brewing science literature showed that hop creep had been noted as far back as 1893 [i,ii]. Back then it was referred to as the “freshening power of hops.” The phenomena was investigated again in 1941 [iii]. The fact that hop creep does not occur in every batch of dry hopped beer allowed it to “fly under the radar” for a while in modern craft brewing.

To begin to investigate the problem, the brewers at Allagash designed an experiment. In it, they dry hopped an American Pilsner-style beer (Coors Banquet) to see if they could induce hop creep, although it was not yet called that. They found out that dry hops alone added to the beer did not result in hop creep. Neither did adding just brewers yeast. However, if the brewers added both dry hops and brewers yeast, hop creep resulted.

The brewers then contacted Tom Shellhammer’s brewing science lab at Oregon State University. As the result of their experiments and others, a tentative explanation is emerging [iv, v]. After mashing, the sweet wort is composed of fermentable extract (composed of maltose and other simple sugars) and the real (or residual) extract, which includes the longer-chained carbohydrates that brewers call dextrins. During fermentation, the fermentable extract is consumed by the yeast and the longer-chained carbohydrates from the residual extract remain.

As with all plants, hops contain amylolytic enzymes, which degrade starch. These include alpha-amylase, beta-amylase, amyloglucosidase, and limit dextrinase. In some dry hopped beers, these enzymes dissolve from the hops and into the beer. There, they begin to catalyze their respective reactions. In particular, much as it happens in the mash, the combined action of these enzymes produces maltose from the longer-chained carbohydrates in solution. The activity of these hop-derived enzymes is substantially lower than their activity in malt. However, the enzymes are present in concentrations such that they can be detected by simple assay.

The maltose released by the hop enzymes is then consumed by the residual yeast in the beer, lowering the terminal gravity and increasing the alcohol and carbon dioxide levels. As in early primary fermentation, diacetyl may be produced as well. However, unlike in primary fermentation, there may not be enough yeast left in the beer to reduce the diacetyl quickly.

Detecting Hop Creep

Detecting hop creep is not difficult. Most breweries monitor the terminal gravity of their beer throughout the process. Likewise, breweries sample beers for vicinal diketones (VDKs, including diacetyl) and monitor the carbonation levels before and after packaging. If all of these go out of specification (in the right directions) following dry hopping, hop creep is likely the culprit. It’s also possible, though not likely, that occasionally dry hopping contaminates a beer with a beer-spoiling microorganism. However, this has been ruled out as a general cause of hop creep. Additionally, the theoretical possibility that hops contained fermentable sugars has also been ruled out.

A forced fermentation test can help a brewery quickly assess if a batch will develop hop creep. To perform this test, a brewer should take two samples of the beer before it is dry hopped. One sample is then dry hopped at the same rate, or higher, than the production batch. The other, the control, is not dry hopped. A brewer could also take a sample of the beer before dry hopping and a sample from the fermenter afterwards. These two samples are held around 80 °F (27 °C) and monitored for the next few days. If fermentation occurs in the dry hopped sample, but not the control, the brewery can expect hop creep to occur in that batch. If both samples are stable after three days, hop creep will not occur. The onset of hop creep quickly follows dry hopping, so a forced fermentation test may only give the brewery an answer a few hours before their QC lab detects it in the production batch.

How to Combat Hop Creep

The rate of every chemical reaction is influenced by time, temperature, concentrations of substrate and reactants, and the presence of catalysts. Hop creep can be thought of as two sets of reactions, the enzyme-catalyzed degradation of dextrins and the enzyme catalyzed series of reactions that we call fermentation. Also, three things are required for hop creep to appear — dry hops (and their enzymes), a beer with dextrins remaining after fermentation, and brewers yeast. When viewed this way, suggestions for avoiding or limiting hop creep are easy to formulate.

If a brewer reduces the hop contact time, hop creep can be lessened. Keep in mind however, that hop-derived amylolytic enzymes will likely still be in solution after the dry hops are separated from the beer. They can continue to break down dextrins in a tank or in packaged beer. Reducing the dry hop contact time to zero solves the problem, with the side effect of reducing hop aroma.

Both the dextrin-degrading reactions and fermentation process proceed at a greater rate at higher temperatures. Dry hopping at cooler temperatures will slow these reactions. Shellhammer's publications recommend the beer be held under 50 °F (10 °C) when dry hopping. Lower temperatures can reduce hop creep in the cellar, but packaged beer may be subject to warmer temperatures downstream — potentially resulting in over carbonated beers with the aroma and flavor of diacetyl.

The concentration of dextrins, hop amylolytic enzymes, and yeast all influence the rate of hop creep. A brewery could reduce the intensity of hop creep by making wort that is more fermentable — one in which the percentage of fermentable extract is higher than normal and the percentage of real extract is lower. This, of course, would alter the character of the beer. In particular, the beer would have a drier mouthfeel.

Brewers could also reduce the amount of dry hops added to their beer. Publications on the topic suggest less than 2.0 pounds (0.91 kg) per barrel. Better yet, brewers could use forms of hops that contain less plant material — T45 pellets, cryo hops, or CO_2 extracts. All of these contain more lupulin gland material and less green matter compared to whole hops or T90 pellets. This also would allow the brewery to retain the dry hop character of the beer, but lessen the impact of hop creep.

In addition, research has shown that more highly-kilned hops are less likely to induce hop creep. This is very likely due to the heat denaturing the amylolytic enzymes. If brewers can source hops kilned to their specifications, they could reduce hop creep.

If the yeast density is reduced in a dry hopping vessel, hop creep can be reduced. Allowing some time after primary fermentation and perhaps lowering the temperature will let more yeast flocculate. And of course, sterile filtration or pasteurization would completely eliminate any yeast in solution.

A combined approach, based on the above, would be to crash cool the beer after fermentation. This would force the yeast to flocculate quicker than normal. Dry hop with a lupulin-enhanced form of hops at below 50 °F (10 °C). Separate the hops from the beer as soon as the desired hop aroma is achieved. And finally, sterile filter or pasteurize the beer to remove any remaining yeast.

Embracing Hop Creep

Another approach to hop creep is to force it to go to completion in the cellar. That way, it will not appear in the packaged beer that has left the brewery. To do this, the brewer would do all the things that encourage hop creep — dry hop with whole hops added to “warm” beer immediately after fermentation so that plenty of yeast is still in suspension. The brewer would then need to monitor the specific gravity and ensure that, after some time has elapsed, the beer is stable and that diacetyl and other VDKs have been reduced. Then the beer could be packaged. This approach can also help with diacetyl reduction as these warmer temperatures will speed the uptake of this compound.

Brewers could also deal with the diacetyl problem directly by adding alpha acetolactate decarboxylase (ALDC). This enzyme converts alpha-acetolactate, the precursor to diacetyl, directly to acetoin. Acetoin is a molecule with a very low aroma and flavor threshold.

It is interesting to note that the brewers from the 1890s regarded hop creep as a good thing. They dry hopped casks of real ale to lower the terminal gravity and leave the beer more biologically stable. For this reason, they called the phenomena “the freshening power of hops.”

Hop creep is now recognized as a potential problem by modern craft breweries. The basic process is fairly well understood — amylolytic enzymes in hops spur a renewed fermentation in dry hopped beer. And, given this information, there are certainly some ways to lessen hop creep. Dry hopping is a widely used technique, so more research will certainly be done on the topic. There are many potential avenues to pursue. For example, it is at least theoretically possible that exogenous proteinases that degrade amylolytic enzymes could be used to counter hop creep.

By Dr. Chris Colby

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[ii] Brown, H. T., and Morris, G. H. 1893. On certain functions of hops used in the dry-hopping of beers. The Brewer’s Guardian, 23, 107-109

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