External dry hopping: The solution for problems? (Part 1)

AROMA EXTRACTION | Dry hopping poses challenges for brewers all over the world. These range from high beer losses, significant effluent pollution, low extraction efficiency to the hop creep effect. This three-part series of articles highlights the main concerns and provides an approach for finding a solution. The approach presented ranged from lab tests with just a few litres up until first industrial projects with batch sizes of more than 3500 kg of hops.

"ONE POUNDWEIGHT of the best hops, as taken from the pocket, should be infused into each barrel of ale", this is the recommendation of Herbert from 1872 for brewing Pale Ale [1]. Addition of hops to beer barrels seems to be one of the most original techniques for so-called dry hopping and can be traced back to 1687 [2]. In the last 130 years, breweries used the most diverse techniques for aqueous extraction of hops after fermentation based on former practices [3, 4].

All techniques have in common that hops, having the desired concentration, is added to respective tanks and that aroma components are extracted based on the particular maximum concentration gradient. In the first half of the last century, hop additions of just a few hundred grams per hectolitre were quite common [5–7] whereas, today, beers with, in some instances, addition of more than 2.2 kg/hl, possibly in various steps, are no exception [8, 9]. In view of increased demand for hop-accented beer styles, such as e.g. New England IPAs, hop quantities added rose steeply. A survey carried out by Dick Cantwell and Chris Swersey [10] showed an increase in hop quantity dosed per hectolitre from on average 456 g/hl in 2011 to more than 664 g/hl in 2019.

Brewers all over the world are facing new challenges when processing such enormous hop quantities efficiently and trouble-free, in particular in view of increasingly automated plants.

Looking at this environment, most brewers will be facing at least one of the problems listed below:

Handling

Supplying a few kilograms of hops into the fermenter or storage tank is usually not a problem in small operations. Manual dosage of, e.g., 500 g/hl into a 1500 hl tank through the tank manhole, having a total bulk volume of almost 1.5 m3, or 150 film bags each holding 5 kg is time-consuming and complex.

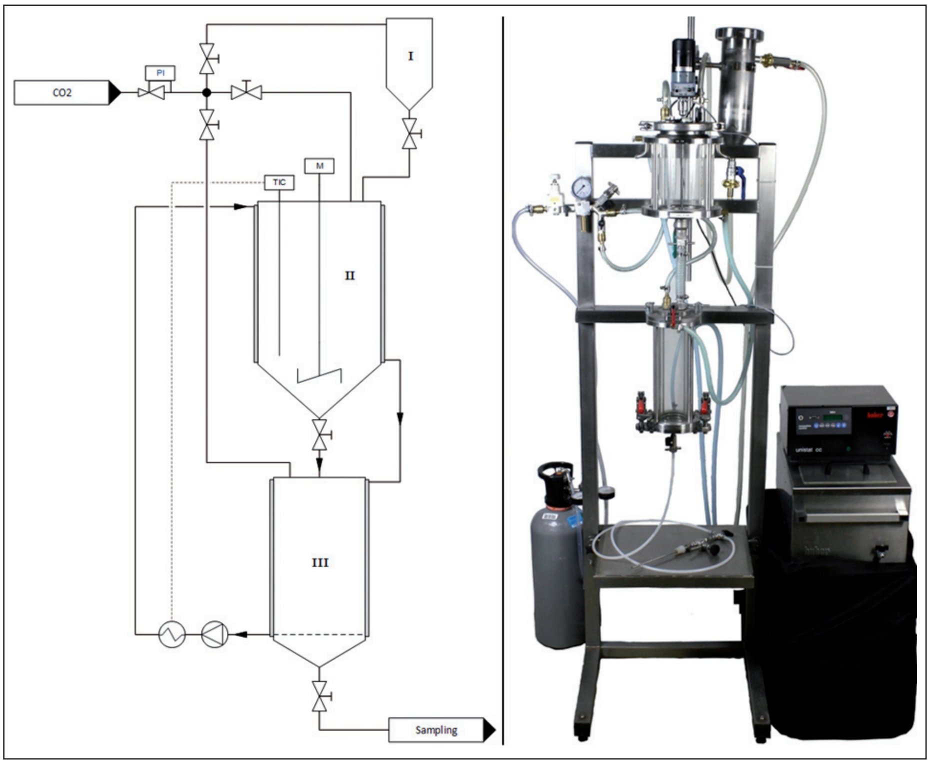

Fig. 1 Schematic and photo of test plant used

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Safety

Apart from these rather cumbersome but possibly manageable obstacles, regulations relating to labour and safety laws are also encountered frequently. In many breweries, lifting equipment has to be purchased in order to bring hops and operatives safely to the tank manhole or filling opening. Operatives have to be protected from falling off tanks, however this is often ignored. Addition to beer already carbonised frequently triggers spontaneous release of carbon dioxide and, thus, severe gushing-type tank fobbing.

Inadequate extraction efficiency

Following dosage of hops usually in pellet form, transfer between aroma substances and beer begins. Depending on technical equipment in breweries, results may differ significantly. In some instances, it takes several hours until pellets in the cold section disintegrate completely into their primary particles without mechanical assistance and the maximum extraction surface area is obtained. During that time, pellets have mostly completely sedimented to the bottom. Without effective means of circulating or mixing the tank in order to bring the hop particles into intimate contact with the complete tank volume, only a fraction of available hop aromas is extracted. At the end of the dry hopping process, complete hop pellets are frequently still found in the tank sediment. These have not disintegrated or swollen. Dissolution of pellets when using bags or similar aids filled with hops is even more inadequate.

Cumbersome removal of hop particles

Even when hops have been completely extracted, hop particles still have to be removed from the beer prior to filling. Due to swelling, the pellet mass added produces an excess of hop sludge which has to be separated. Brewers should expect at least 6–7 l of hop sludge per kg of hop pellets added. Under ideal conditions, 750 kg of hops, e.g. produce about 4.5 m3 hop sludge swollen with beer. In order to remove this from the tank, a process is used similar to yeast sludge removal or yeast cropping. In automated fermentation and storage cellars, haze measurement is also an option. This process presupposes that the hops have sedimented completely. However, in view of the uneven particle size distribution and today's often cylindroconical tank geometry, this can take longer than storage time originally planned. Apart from high manual workload in non-automated cellars, tank residence times are prolonged, thus reducing cellar capacity further.

Disposal of these hop quantities is also problematic. Discharge into the municipal waste water is in most instances not possible or only under strict conditions due to the elevated amounts of solids and COD values.

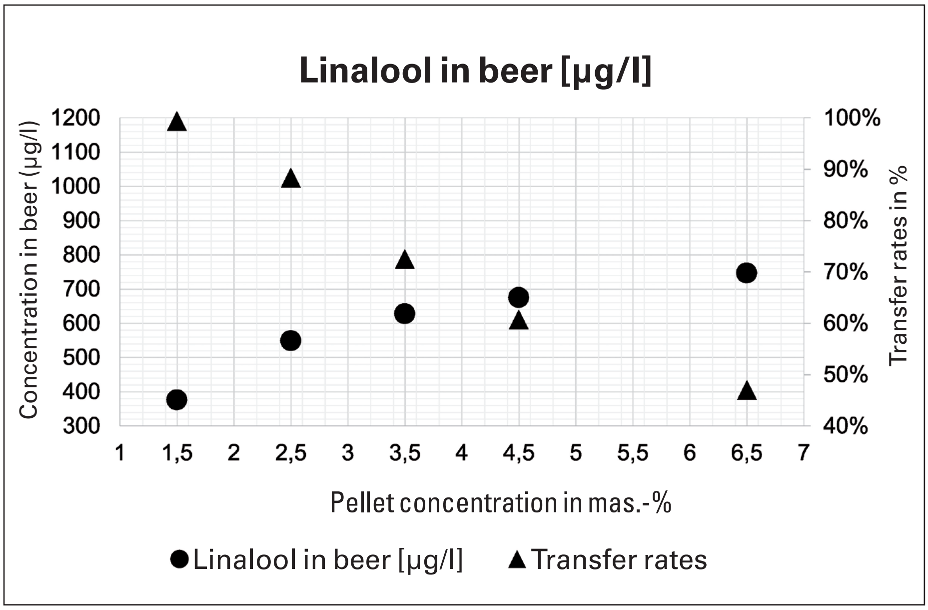

Fig. 2 Linalool concentration and linalool transfer rates after a mixing time of 1 h as a function of hop mass concentration added

Hop creep

Apart from the fact that hop particles have to be removed, the so-called hop creep effect is another problem. As the whole plant matrix is added, small amounts of carbohydrates and the enzymes amyloglucosidase and dextrinase are carried over into the beer. Hop bracts and bracteoles, in particular, have a high enzyme activity [12]. These enzymes supply yeast again with fermentable sugars and might thus trigger another fermentation. If this overfermentation is not taken into consideration during storage, unwanted diacetyl might be formed and, in the worst case, uncontrolled secondary fermentation might take place in the bottle.

This so-called hop creep effect has to be accepted to-date as contact time between

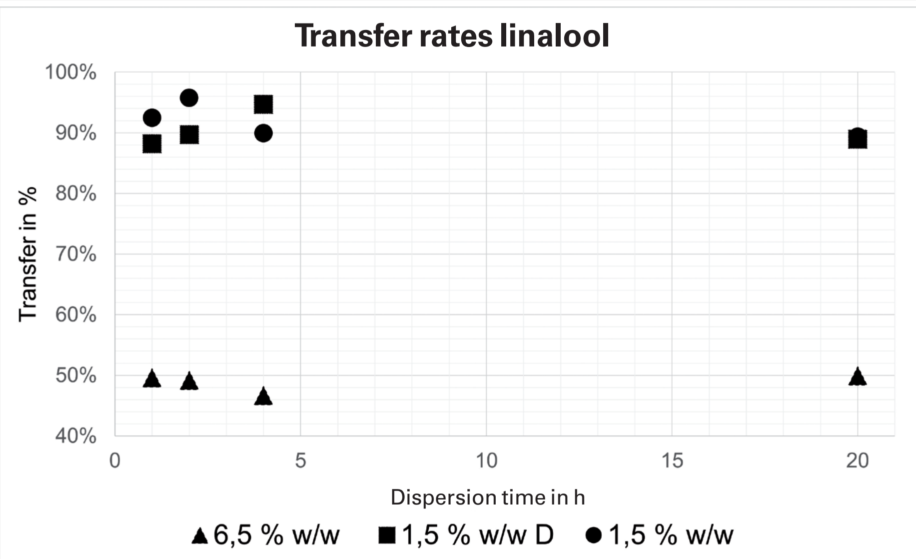

Fig. 3 Linalool transfer rates as a function of mixing time

hop particles and beer can be controlled only to a limited extent.

Beer losses

If hops were removed from the tank completely and ideally, without the beer quantity required for swelling, beer losses would already be about 3–4 per cent when dosing just 500 g/hl. However, additional beer losses in the interstices of sedimented hop particles and due to inefficient and frequent sludge removal have to be expected.

Further losses might occur in downstream processes such as more frequent "cropping" of downstream centrifuges in view of higher haze values or particle contents.

Accordingly, beer losses of 8–12 percent during dry hopping, when just 500 g/hl are added, are not uncommon in breweries. When a 1 500 hl batch is produced, 180 hl of potential sales beer can indeed be lost, these are usually in the higher price segment in view of the elaborate process and the expensive and large hop quantities added.

Technical failures caused by hop particles

Problems when running centrifuges for beer clarification frequently arise due to partly very large particles and their inhomogeneous distribution in the beer tank. Problems caused by blocked centrifuges resulting from dry hopping are meantime so common that some breweries operate several centrifuges in parallel to be able to continue production when a centrifuge fails. The discs of the blocked centrifuge have to be disassembled and cleaned by hand, a labour-intensive job.

Apart from blocking centrifuges, hop particles also cause other problems as they form deposits in tanks or in the piping system so that relatively large quantities of organic material get into the CIP system. They block tank spray balls or jet cleaners and removing them requires increased use of media.

Plant manufacturers and brewers are facing major challenges in remedying these problems. No system has yet been developed which can simultaneously solve all these problems.

Possible solution: new dry hopping concept

As recommended by Herbert [1] and others, hops were always brought to the beer in the past, the basis of almost all problems mentioned. The basic idea of the novel dry hopping concept reverses this approach i.e. bringing the beer to the hops in a central plant for extraction in order to carry out inline extraction so to speak. The problems mentioned could be solved if hop pellets were extracted sufficiently fast and, at the same time, all particles were separated, while obtaining high dry matter contents.

During the last two years, banke GmbH, Taufkirchen, Germany, together with hop refiners, has studied the feasibility of a new dry hopping concept step by step. This is based on the concept that the highest possible mass concentration of hops is suspended in beer, that hop aromas are transferred into the beer as completely as possible and that the resulting high-concentration, dry hopped liquid beer phase is returned again to the beer, free of hop particles.

Preliminary tests for extraction

An existing, three-part universal extraction and filtration plant was used for the feasibility tests (fig. 1). The plant was used for carrying out extraction tests on a scale of just a few litres with a very high reproducibility.

It could be shown in preliminary tests that an increase in hop mass concentration resulted in reduced aroma transfer. In these tests, different mass concentrations of

Fig. 4 Hop-beer suspension with 1.5 per cent by mass (l) and 6.5 per cent by mass (r)

hop pellets of Cascade type 45, with an oil content of 0.7 ml/100 g, were suspended in pale vollbier (5 v/v % alcohol, pH 4.3) and a sample was taken after 1, 2, 4 and 20 hours. Fig. 2, taking the linalool aroma component as an example, showed a significant decrease in percentage aroma transfer. The transfer rate should be interpreted as a percentage share and indicates the amount of aroma component from the hop pellets originally added that was recovered and analysed in the liquid beer sample.

At a pellet dosing rate of 1.5 per cent by mass, approximately 100 per cent of linalool is transferred to beer within one hour of constant stirring. However, this value drops to below 50 per cent at a dosage rate of 6.5 per cent by mass. This decrease in aroma transfer should not be confused with reaching a solubility limit. The solubility limit of linalool, when dry hopping, is about 1556 mg/l [13] and thus higher by a factor of 100 than in our sample.

As shown in fig. 3, aroma transfer from linalool was concluded after just one hour and could not be raised when prolonging mixing time, both for a concentration of 1.5 and 6.5 per cent by mass. However, it was also noted that re-dilution of the suspension of originally 6.5 per cent by mass down to 1.5 per cent by mass shortly before filtration and a contact time of about 90 s resulted in the same transfer rate observed for a sample originally produced with 1.5 per cent by mass.

This data confirms the results of Lafontaine and Shellhammer [8] from 2018, showing a drop in extraction rate as a function of hop mass concentration for different aroma components in static dry hopping.

Based on these first findings, it is not expedient to extract high concentrations of hops in beer, followed by immediate separation of hop particles in order to produce a dry hopping concentrate. This lowers extraction efficiency and/or aroma transfer does not take place completely so that aroma hops have to be discarded without having been used.

As a first test showed that re-dilution of the suspension of 6.5 per cent by mass – where just 50 per cent of linalool was extracted – down to a mass concentration of 1.5 per cent results in an immediate increase in aroma transfer, further tests were carried out (fig. 4).

It if were possible to confirm and reproduce these results, simplified and optimised extraction would be possible when hops are extracted inline outside the fermenter and immediately separated again.

The results of tests based on the preliminary test will be discussed in detail in the second part of this series of articles.

References

1. Herbert, J.: “The Art of Brewing India Pale Ale and Export Ale, Stock & Mild Ales, Porter & Stout”, 5th. ed., self-publication, Burton-upon-Trent, 1872.
2. Hohberg, W. H. von: “Georgica Curiosa”, Nuremberg, 1687.
3. Cocuzza, S.; Mitter, W.: “Revival of a Process: Dry Hopping – Basics and Techniques”, Brewing and Beverage Industry International, 3 (2013), pp. 28–30.
4. Narziß, L.; Back, W.; Gastl, M.; Zarnkow, M.: “Abriss der Bierbrauerei”, 2017.
5. DeClerck, J.: “A Textbook of Brewing”, vol. 1, Siebel Institute of Technology (ed.), 1994.
6. Moritz, E. R.; Morris, G. H.: “A Textbook of the Science of Brewing”, Spon, 1891.
7. Burgess, A. H.: “Hops: Botany, cultivation and utilization”, Interscience Publishers, Inc., New York, 1964.
8. Lafontaine, S. R.; Shellhammer, T. H.: “Impact of static dry-hopping rate on the sensory and analytical profiles of beer”, Journal of the Institute of Brewing no. 4, 124, 2018, pp. 434–442.
9. Hauser, D. G.; Lafontaine, S. R.; Shellhammer, T. H.: “Extraction Efficiency of Dry-Hopping”, Journal of the American Society of Brewing Chemists, no. 3, 77, 2019, pp. 188–198.
10. Cantwell, D.; Swersey, C.: “A New 2019 BA Hop Usage Survey”, The New Brewer, 2019.
11. Brynildson, M.: “U.S. Hops and the American Craft Beer Revolution”, 2018.
12. Shellhammer, T. H.; Kravitz, M.; Beauchamp, A.; Vaughan, C.; Cilruzo, V.: “Hop creep?: What it is and approaches to managing it”, Craft Brewers Conference, (2018).
13. Haslbeck, K.; Minkenberg, D.; Coelhan, M.: “Investigations into the Transfer Rate of Volatile Compounds in Dry Hopping Using an Octanol-Water Partition Coefficient Model”, Journal of the American Society of Brewing Chemists no. 3, 76, 2018, pp. 169–177.