SUPPLIER PERSPECTIVE

# Revolutionary Dry-Hopping Techniques for Larger Beer Volumes Using the Iso-Mix External Drive Rotary Jet Mixer

**Alyce Hartvigsen**

Alfa Laval Copenhagen A/S, Soborg, Denmark

**ABSTRACT**

A "revolution" in the craft brewing industry has led to high demand for dry-hopped beers and increasing production in breweries both small and large. However, there are many challenges associated with the automation and scale-up of dry-hopping techniques to larger beer volumes. These include efficient introduction of the hops without excessive oxygen pick-up, effective extraction of the aroma compounds into large beer volumes, removal of the hops while minimizing product loss, and efficient cleaning in place of the system. Most existing dry-hopping systems in the market exhibit capacity limitations, are difficult to clean by automated clean-in-place processes, and are challenging to integrate into automated modern breweries. The potential of rotary jet mixers for dry-hopping applications has been considered, but the high particulate loads in the fluid require a special mixer design. Alfa Laval has developed the Iso-Mix external drive system, a new type of rotary jet mixer suitable for dry hopping of larger beer volumes. The system homogenizes hop distribution in the beer, potentially reducing the required quantity of hops while attaining the desired flavors. Homogenization continues during transfer to downstream centrifugation, improving the separation efficiency and product clarity. It is easily automated and allows flexibility in the method of hops introduction. The process configuration is similar to conventional rotary jet mixing systems, and as such, the system can also be used to optimize the fermentation, maturation, and crash-cooling processes. This article examines the challenges of large-scale dry hopping and demonstrates how the new system improves the dry-hopping process for larger tanks.

Keywords: Dry hopping, Mixing, Homogenization, Extraction, Separation, Extract loss

Dry hopping involves the addition of hops to the fermentation and/or maturation vessels, either before or after primary fermentation, to extract the hop flavors and aromas into the beer that cannot be obtained through hopping in the brewhouse. The practice has become widespread in recent years, as pale ale and India pale ale styles have gained popularity in the market.

For the purpose of this discussion, only dry hopping using hop pellets (as opposed to whole hop cones) will be considered.

The dry-hopping process itself, if done using hop pellets, can be roughly divided into four main stages:

- Introduction of hop pellets into the system
- Disaggregation (swelling and slurrying) of the hop pellets
- Extraction of the aromas and flavors into the beer volume
- Removal of the hop particles from the beer

The characteristics of each stage can be summarized as follows.

## Introduction of the Hops into the System

The main challenge of hops introduction is conveying the material into the system without excess oxygen pick-up. Typical methods for hops introduction include the following:

- Pouring the hops directly into the fermentation or maturation tank—the typical practice for smaller tanks in craft breweries but not feasible for larger tanks and hop quantities
- Preparation of a hop slurry in a small tank and pumping of the slurry into the main tank (fermenter or maturation vessel)
- Direct transfer into the tank—for example, using $CO_2$ as a conveying gas (e.g., the "hop cannon" process)
- Filling of the hops into an enclosed strainer system through which beer is circulated (e.g., the HopGun system)

Alyce Hartvigsen was born in Philadelphia, PA, in 1967 and completed her B.Sc. in chemical engineering at Case Western Reserve University in 1988. She began her career in process engineering in the petrochemical industry. In 1994, she accepted a technical sales position with a Danish technology company in Houston, and she moved to Denmark in 1997. Her arrival coincided with the beginning of the craft beer "revolution" in Denmark, and over the years, she developed a keen interest in beer and brewing, joining the Danish Beer Enthusiasts and a home-brewing club. In 2012, she took advantage of a unique opportunity to combine career and personal interest and joined Alfa Laval as a sales and technology manager in the brewery market unit. She is responsible for the global sales and technical support for rotary jet mixers and other tank equipment for breweries. Her work has primarily focused on developing and promoting applications for rotary jet mixing in the brewing industry. She has overseen the implementation of both commercial-scale trials and full cellar installations, and she works closely with the end users in the commissioning and process optimization of the systems. Present activities include expanding the applications for rotary jet mixing within the fast-growing craft brewing sector.

E-mail: alyce.hartvigsen@alfalaval.com

http://dx.doi.org/10.1094/TQ-54-4-1122-01

### Disaggregation

Swelling and slurrying of the hops occur when there is contact between the hops and liquid (beer and/or water), and the hop solids absorb liquid and begin to break apart. The rate of swelling is dependent on the fluid temperature and the circulation rate of liquid through the pellets. Typically, the observed volume increase of the solids from swelling and liquid absorption is five to six times the initial pellet volume. This growth rate can easily lead to plugging and caking of the hop mass and cessation of fluid flow through the hops, if insufficient space is available to accommodate the volume growth. Channeling through the hop mass is also common, limiting the extent of mass transfer and leading to poor hop utilization.

### Extraction

The main objective in dry hopping is the extraction of the hop volatiles (aromas/flavors) into the beer. Extraction rates are dependent on factors such as fluid temperature, surface area of the hop–beer contact, and mass transfer mechanisms (e.g., fluid circulation rates).

### Removal

Following extraction, hops removal is typically done by settling and cropping, centrifugation, or both. The high particulate concentrations and tendency for the residues to settle and pack often cause plugging of pipelines, heat exchangers, filters, and other process equipment, sometimes leading to prolonged process shutdown as the brewery works to clear the blockages.

Figures 1 and 2 provide examples of conventional dry-hopping process configurations attempted at a customer site, and Figure 3 summarizes the challenges arising from various aspects of these processes and possible mitigating actions for each, as evaluated by this customer.

## Dry-Hopping Issues in Practice: Solids Carryover to Filtration and Blockages

Figures 4 and 5 provide a clear example of the challenges that breweries can face during large-scale dry hopping. In this example, dry hopping has occurred in the maturation tank, and the hop residues have been removed from the tank bottom as sludge after 3–5 days of settling time. Following hops removal, the beer is then transferred to the polishing centrifuge and thereafter to membrane filtration.

The beer is clear and free of hop solids during most of the transfer to filtration, but when the tank is nearly empty, slugs of hop particulates begin to emerge from the tank. The last few hectoliters of material leaving the tank are virtually all hop solids (Figure 4). The prefilter centrifuge is unable to cope with these high solids concentrations (Figure 5), and solids carryover occurs into filtration, causing membrane and line plugging and requiring hours of downtime to clear the blockages.

## Mixing and Homogenization During Dry Hopping

Many of the more difficult issues associated with dry hopping can be addressed by mixing of the hop particles in the liquid:

- Mixing during hops introduction accelerates the contact of the pellets with the liquid, and it promotes swelling and slurrying.

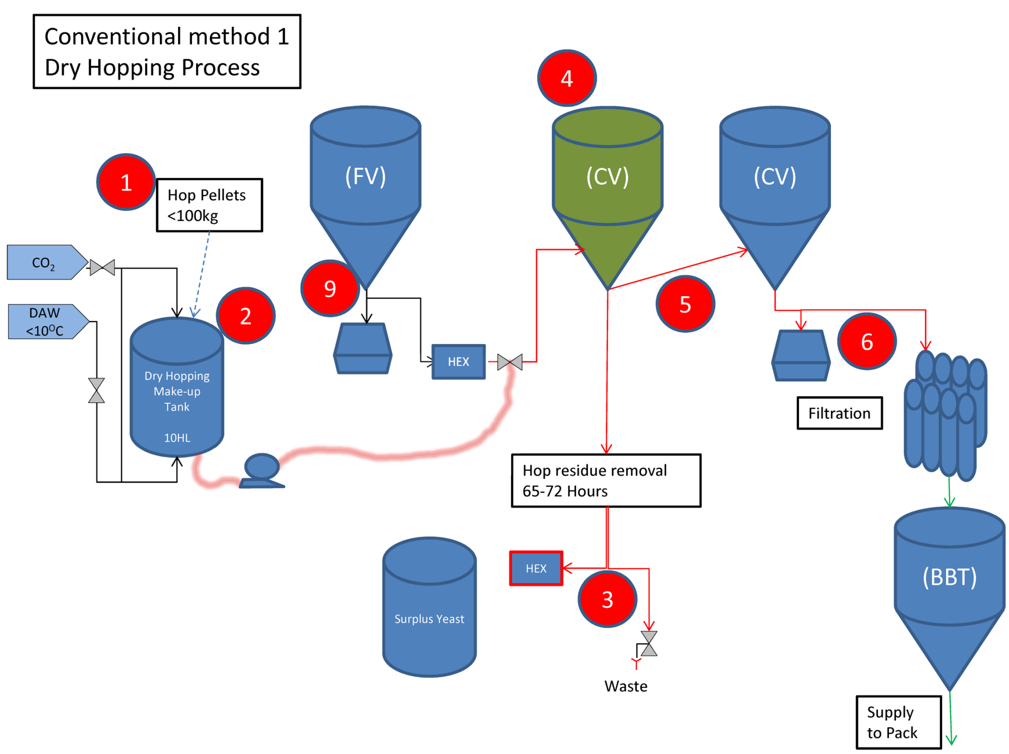


**Figure 1.** Conventional dry hopping, method 1. Numbers correspond to Figure 3. DAW = deaerated water; FV = fermentation tank; CV = maturation tank; BBT = bright beer tank; and HEX = heat exchanger.

- Mixing during disaggregation helps to homogenize the particle distribution in the liquid, and it can prevent caking of the swelling solids and potential blockages.
- Mixing during aroma and flavor extraction promotes the transfer of the flavor compounds to the entire beer volume, and it can greatly reduce the time required to attain the required flavors in the beer.
- Mixing during particle removal from the beer maintains a homogeneous solids concentration during transfer to centrifugation, providing a consistent load to the centrifuge,

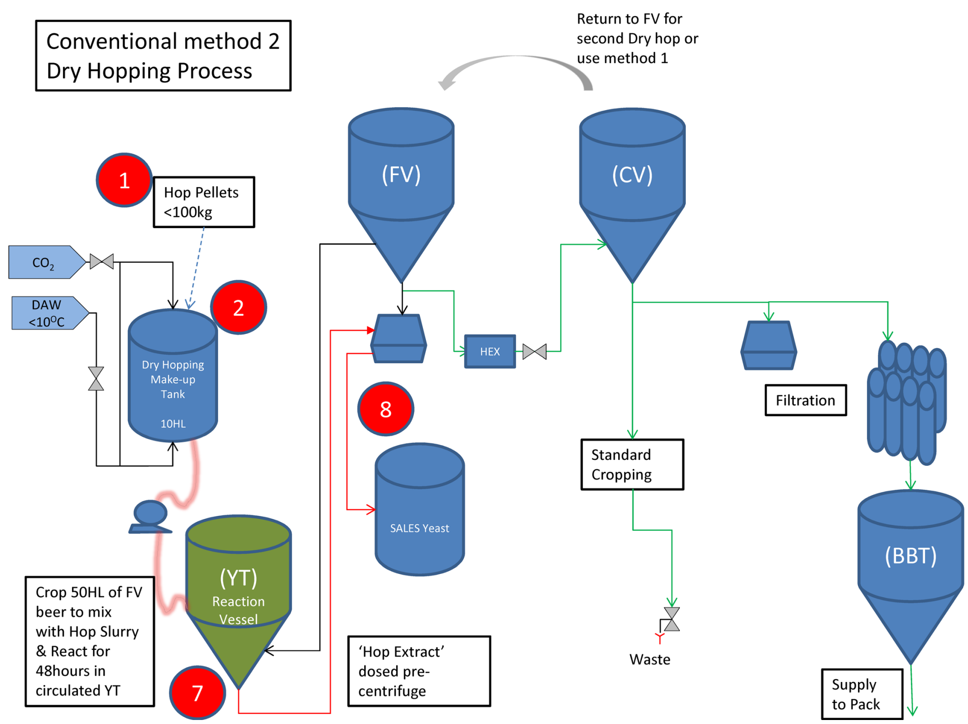


**Figure 2.** Conventional dry hopping, method 2. Numbers correspond to Figure 3. DAW = deaerated water; FV = fermentation tank; CV = maturation tank; BBT = bright beer tank; HEX = heat exchanger; and YT = yeast tank.

| | Area | Issue | Mitigation |
|---|---|---|---|
| 1 | Dry hop make-up tank | Ingress of dissolved oxygen. | $CO_2$ rousing of tank. |
| 2 | Dry hop make-up tank volume | Batch size of dry hopping restricted. Overloading can result in pumping problems. | Restrict batch sizes.<br>Make up 2nd batch during transfer. |
| 3 | Hop residue removal | Excessive residues can give blockages and overflow. | Unclog drains and clean area after cropping.<br>Crop to yeast tank for discharge to drain. |
| 4 | Hop residue removal | High extract loss – commonly 10–15% over maturation/filtration dry-hopped beers | None. |
| 5 | Hop residue removal | Hop residue not reliably removed. Some solids float in tank. Level probes damaged by hop residue. Last 10 hL in tank is not liquid. | CV-CV transfer prior to filtration. |
| 6 | Filterability | "Slugs" of hop residue can carry through centrifuge and block filter membranes. | CV-CV transfer prior to filtration. |
| 7 | Yeast tank reaction vessel | Centrifugal pump blocks if hops settle too quickly.<br>Planning constraints .<br>Some flavor variation.<br>Quality considerations. | Restrict volume to 50 hL, recirculation speed fixed.<br>Additional lead time on dry hopping. |
| 8 | Solids discharge from centrifuge | Very dense discharge cake blocks line to surplus yeast. | Increase rinsing time on centrifuge discharge.<br>Segregate yeast for animal feed only.<br>Look at skip options for removal. |
| 9 | FV cropping | High solids in FV due to late whirlpool hopping.<br>Can block yeast cropping HEX. | Crop earlier when solids less compact (75% attenuation). |

**Figure 3.** Conventional dry hopping: issues and possible mitigations. FV = fermentation tank, and HEX = heat exchanger.


**Figure 4.** Hop residue concentration gradients during tank transfer to filtration.

**Figure 5.** Carryover of hop solids through prefiltration centrifuge.

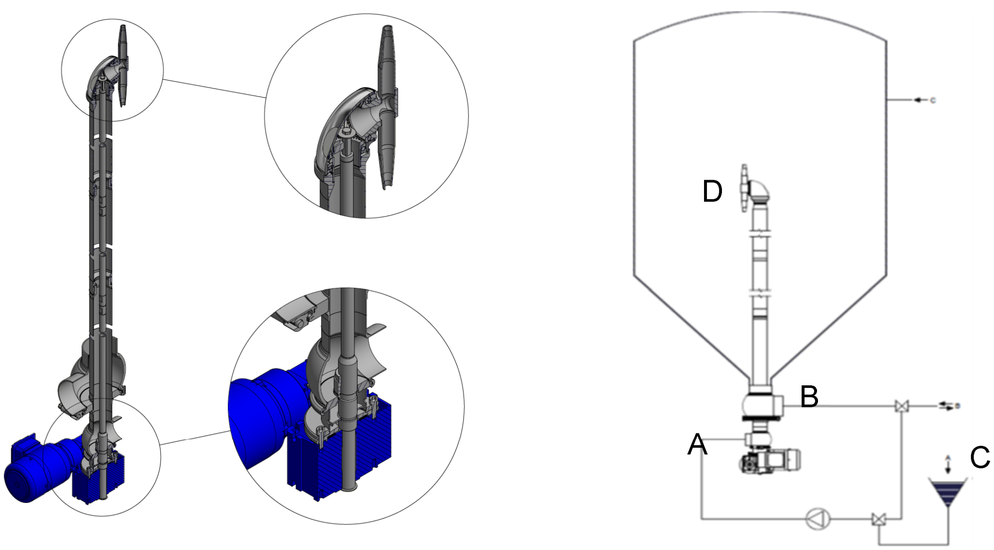


**Figure 6.** Iso-Mix external drive schematic (left) and simple beer circulation loop configuration (right). Labels: A, beer and hops from pump suction to mixer nozzles; B, tank outlet to pump suction; C, hop slurry dosing inlet into circulation loop; and D, mixer outlet through nozzles, dispersing the hop solids throughout the beer volume.

optimizing separation and preventing solids carryover to downstream tanks and filtration.

Mixing during the hops introduction and disaggregation stages is easily facilitated when these steps are performed outside of the main tank, for example, using a top-mounted agitator in the hops introduction/slurry tank. However, implementing a satisfactory degree of mixing in the extraction and removal phases for larger batch dry hopping is difficult, for the following reasons:

- Large volumes to be mixed (typically >250 hL)
- High concentration of solid particles in circulating liquid
- Range in particle sizes, up to 3–4 mm for preslurried hops and up to 10–15 mm for dry hop pellets
- Requirement for a wide range of mixing volumes (typically from 10 to 15% of working volume to full working volume) to enable homogenization during tank emptying

The use of standard Alfa Laval rotary jet mixers was initially considered as a possible solution for the dry-hopping application; however, the standard rotary jet mixers could not handle the high concentration of hop particles in the dry-hopped beer.

## Iso-Mix External Drive (IMXD) for Dry Hopping

The IMXD is a new type of rotary jet mixer that is suitable for applications such as dry hopping, in which there are high concentrations of particulates in the circulating fluid.

In the IMXD, the mixer gears have no contact with the circulating liquid flow, thereby preventing gear plugging and rotation stoppage. The mixer rotation is separately controlled by a small external motor and shaft, and the liquid circulates freely to the mixer nozzles.

Figure 6 provides a schematic illustration of the IMXD unit and a simple configuration of the circulation loop, illustrating the addition of hop slurry into the loop.

Figure 7 depicts the overall dry-hopping process at a customer site, incorporating the IMXD system.

The IMXD unit is installed into the fermenter or maturation tank through the bottom outlet flange. The configuration of the system resembles a standard Iso-Mix bottom-entry solution typically used for optimization of the fermentation process. In some cases, it is possible to retrofit a standard bottom-entry Iso-Mix system to an IMXD system with relatively few modifications. (More information regarding the standard Iso-Mix system is available in a previous *Technical Quarterly* article [2].)

## Functions of the IMXD in the Dry-Hopping Process

The IMXD unit provides efficient mixing of the beer at any or all stages of the dry-hopping process. Examples of its use are as follows:

### Hops Introduction

Using the IMXD for circulation of the base beer in the fermenter or maturation tank prior to and during hops addition facilitates the dispersion of hop solids into the beer, giving greater flexibility in the method of hops introduction. High beer circulation rates through the IMXD during transfer enable the addition of thick hop slurries (>20% solids) into the circulation loop, with fast and effective dispersion into the beer.

Alternatively, dry hop pellets may be added directly to the main tank by gas conveyance through the top. Here, circulation with the IMXD will quickly disperse the hop pellets throughout the beer volume and accelerate disaggregation.

### Disaggregation

Mixing with the IMXD system accelerates the disaggregation and slurrying of any undissolved hop pellets. Whole

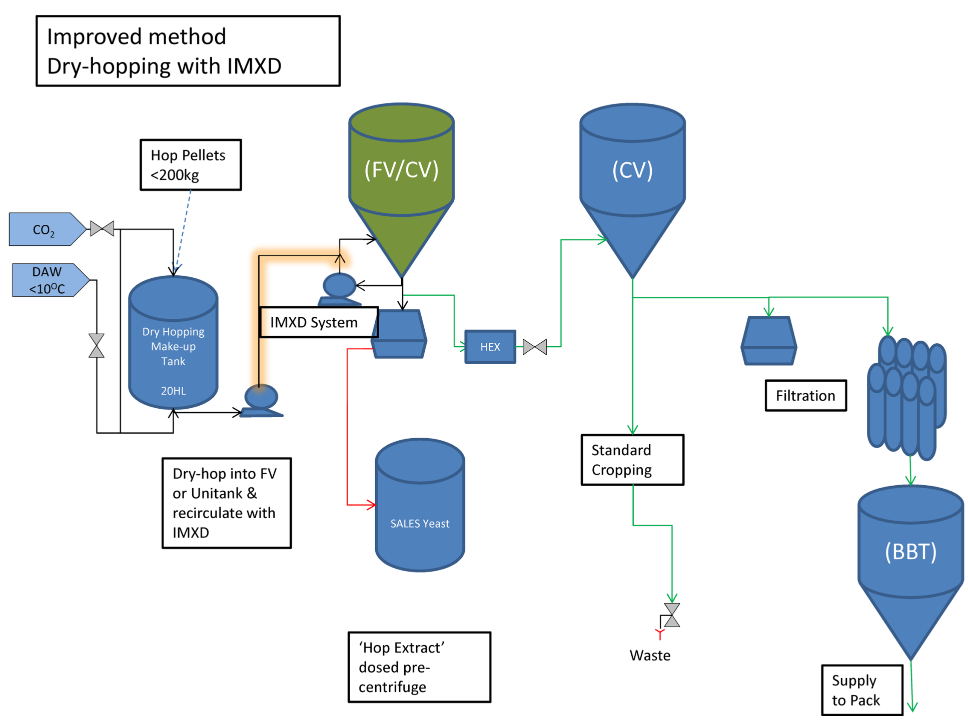


**Figure 7.** Dry hopping with the Iso-Mix external drive (IMXD): overall process. DAW = deaerated water; FV = fermentation tank; CV = maturation tank; BBT = bright beer tank; and HEX = heat exchanger.

pellets added directly to the tank break up during circulation through the centrifugal pump and through the mixer nozzles. If the hops have been preslurried prior to addition to the tank, circulation through the IMXD accelerates the remaining swelling and slurrying and disperses the hop particles throughout the beer. Continued circulation through the IMXD maintains the hops in suspension and prevents premature settling of the hops.

### Extraction

Beer circulation with the IMXD disperses the hop particles and accelerates the extraction of the hop aromas and flavors into the beer. As a result, the required hop residence time can be reduced from days to hours, while still obtaining the desired flavor and aroma profile. Figure 8 compares the measured concentrations of several key hop aroma compounds in beer dry hopped using the IMXD versus the conventional unmixed method. In all cases, the aroma concentrations attained in the beer after 1, 2, 3, or 4 h of residence time using the IMXD exceeded the concentrations attained during up to 3 days of conventional unmixed dry hopping. In Figure 9, it was noted that the concentration of the volatile compound myrcene attained using the IMXD decreased by about 50% after centrifugation of the beer. Similar behavior was observed with other highly volatile compounds such as humulene and carophyllene. It is believed that these aroma losses may be the result of oxygen pick-up and/or evaporation in the centrifuge. In such a case, it is believed that the use of a hermetic, bottom-fed centrifuge could minimize such losses.

### Removal

The low placement of the IMXD unit in the tank allows mixing to continue during the transfer of the beer to centrifugation, until the tank is nearly empty. This operation maintains consistent solids loading to the centrifuge, thereby optimizing separation performance and preventing carryover. Figure 9 illustrates the efficient centrifugation of beer that has been dry hopped with the IMXD system. The photo at the left shows the consistency of the solids discharge from the centrifuge, and the photos at the center and right illustrate the efficiency of the centrifuge in solids removal.

## Observed Improvements in Dry-Hopping Performance with the IMXD

Figure 10 highlights the improvements imparted by the IMXD system to the dry-hopping process during customer trials. The customer observed significant reductions in the total tank residence time, number of tanks required for dry hopping, and overall product loss from the process.

Blind tasting of the dry-hopped beer made with the IMXD process versus that from the conventional process found no significant differences in flavor between the two.

The economic implications of the process improvements obtained with the IMXD system are considerable. The time savings during dry hopping is equivalent to a potential increase in capacity of up to 15%, and the reduction in required tank commitment increases the brewery's flexibility. A 10% decrease in product loss translates to 15% additional beer produced.

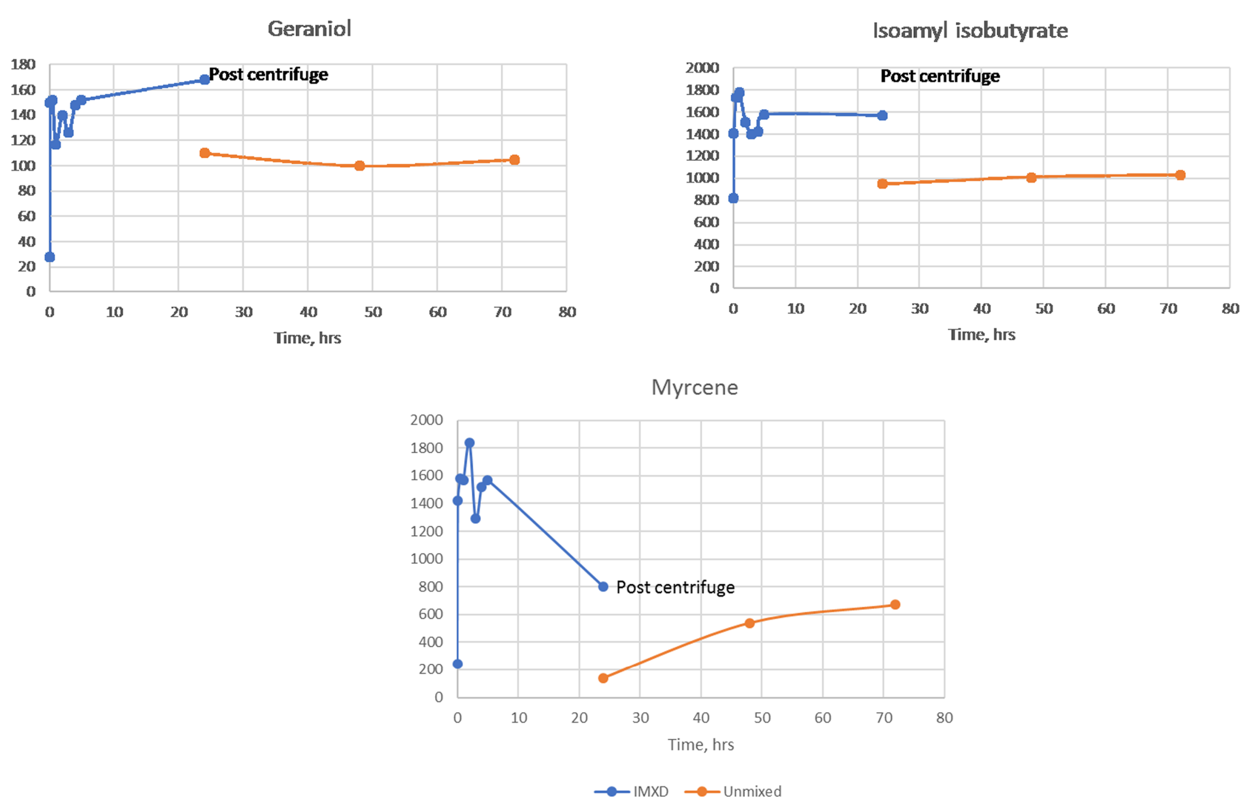


**Figure 8.** Measured concentrations of geraniol, isoamyl isobutyrate, and myrcene in beer dry hopped with the Iso-Mix external drive (IMXD) versus no mixing.

## Conclusions

Dry hopping using the IMXD system addresses many of the process issues associated with the dry hopping of larger beer volumes. The system is suitable for use in tanks ranging in size from 200 to >6,000 hL. It provides full flexibility in the method of hops introduction to the tank, and it facilitates rapid dispersion of the hops throughout the beer and more efficient extraction of the flavors and aromas into the full beer volume. The placement of the mixer low in the tank allows mixing to continue during transfer of the beer to downstream separation, thereby providing homogeneous solids loading to the centrifuge, leading to efficient separation of the residues from the beer. The combination of mixing with the IMXD and centrifugation for removal of the hops residue significantly reduces the beer losses associated with dry hopping. The system is fully

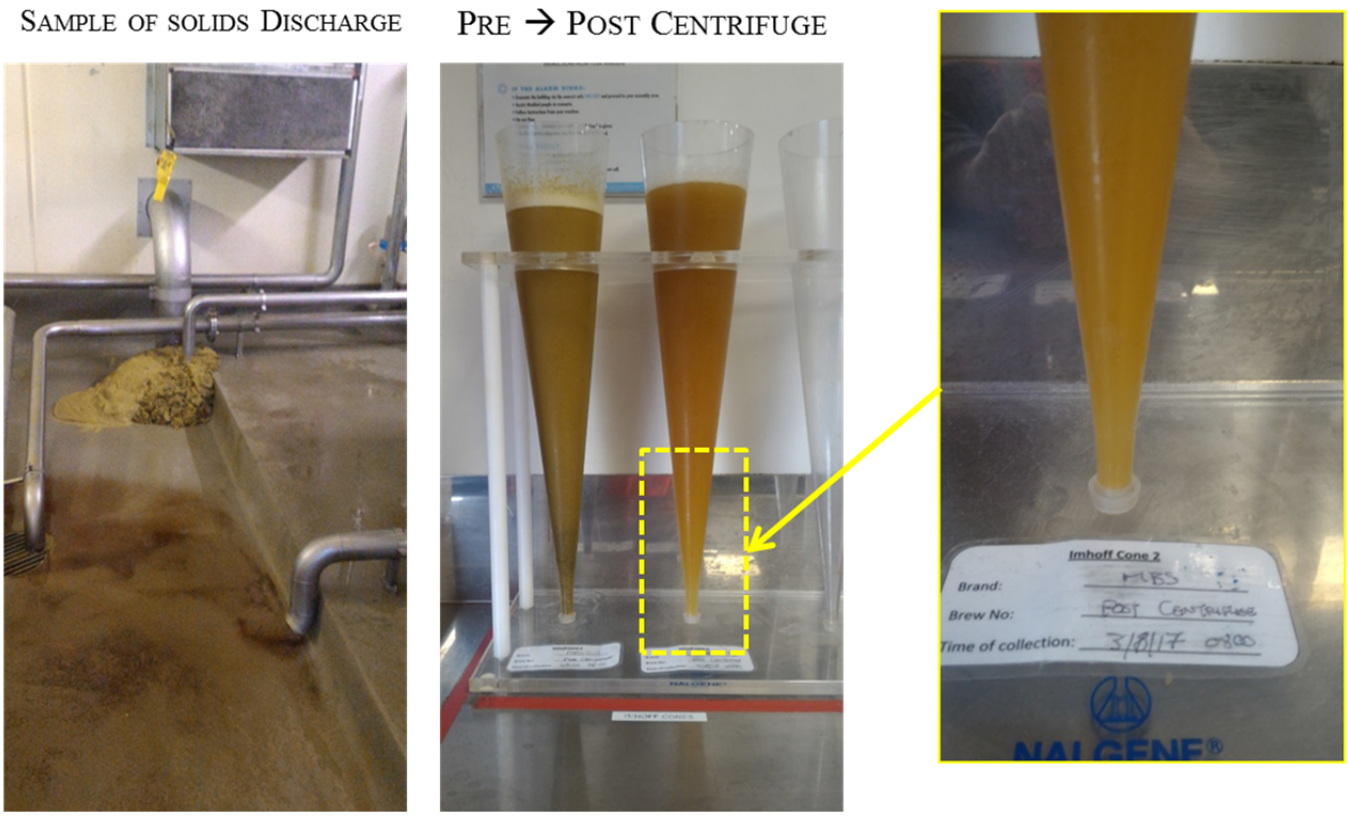


**Figure 9.** Dry hopping with the Iso-Mix external drive: effective removal of hop solids during centrifugation.

| | Brand 1 | | Brand 2 | |
|---|---|---|---|---|
| **Criterion** | **Old method** | **IMXD** | **Old method** | **IMXD** |
| Tank Residence Time (From End of Ferment to Filtration) | 5 - 7 days | <48 hours | 7 - 10 days | <48 hours |
| Number Tanks used | 4 | 2 | 4 - 5 | 2 |
| Cropping loss | up to 10% cold break + hops | Solids Removed through Centrifuge <2% Loss in maturation from cold break | up to 15% cold break + hops | Solids Removed through Centrifuge <2-3% Loss in maturation from cold break |

**Figure 10.** Improvements with the Iso-Mix external drive (IMXD) compared with conventional dry-hopping processes.

cleanable with minor modifications to the normal clean-in-place routine and is easily integrated into a fully automated modern brewery.

The IMXD system can also be used in any standard Iso-Mix rotary jet mixing brewery application, such as fermentation optimization, acceleration of crash cooling, and blending of special products such as ciders and flavored beers.

## REFERENCES

1. Cocuzza, S., and Mitter, W. (2013). Revival of a process: Dry hopping—Basics and techniques. Brew. Beverage Ind. Int., No. 3.
2. Hartvigsen, A. (2016). Dynamic fermentation with Iso-Mix rotary jet mixing: Optimizing yeast viability and system performance. Tech. Q. Master Brew. Assoc. Am. 53(4): 200-204.
3. Kishimoto, T., Wanikawa, A., Kono, K., and Shibata, K. (2006). Comparison of the odor-active compounds in unhopped beer and beers hopped with different hop varieties. J. Agric. Food Chem. 54:8855-8861.
4. Murphey, J., and Probasco, G. (1996). The development of brewing quality characteristics in hops during maturation. Tech. Q. Master Brew. Assoc. Am. 33:149-159.
5. Schönberger, C., and Kostelecky, T. (2011). 125th Anniversary review: The role of hops in brewing. J. Inst. Brew. 117:259-267.
6. Vollmer, D. M., and Shellhammer, T. H. (2016). Dry hopping on a small scale: Considerations for achieving reproducibility. Tech. Q. Master Brew. Assoc. Am. 53(3):140-144.