External Dry Hopping

An approach for improving sustainability by reducing beer losses, wastewater loads and shorter production cycles

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Introduction

Dry hopping has become an important aspect of the production of many beers, not just craft beers. Typically, the process of dry hopping is time-intensive and often inefficient. Moreover, dry hopping often leads to very high beer losses, up to 40 %, in addition to causing problems in the fermentation cellar and elevating wastewater contamination levels.

The aim of this research was to determine whether the substances in the hops can be efficiently extracted, and the hops separated from the beer again, in a continuous external process, i.e., outside of the beer tank, by using a dilution technique to enhance aroma transfer.

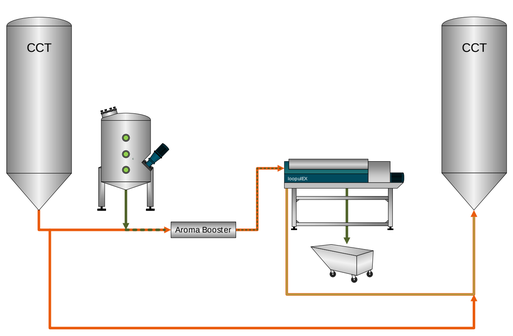


Fig. 1:
External dry hopping system - process schematic

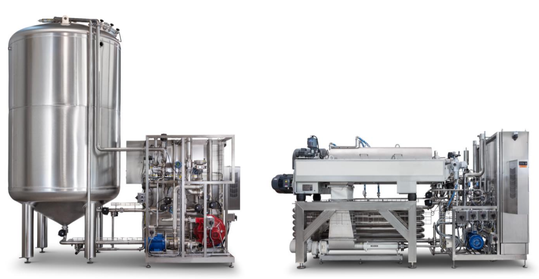


Fig. 2:
External dry hopping system loopulEX® (banke GmbH)

To test this method, experiments were carried out on a laboratory set-up (fig. 3) to measure the influence of mass concentration and dilution on the mass transfer of bitter compounds, esters, terpenes and thiols. In addition to GC and HPLC analysis, the sensory attributes were evaluated by a panel of trained tasters.

Methods

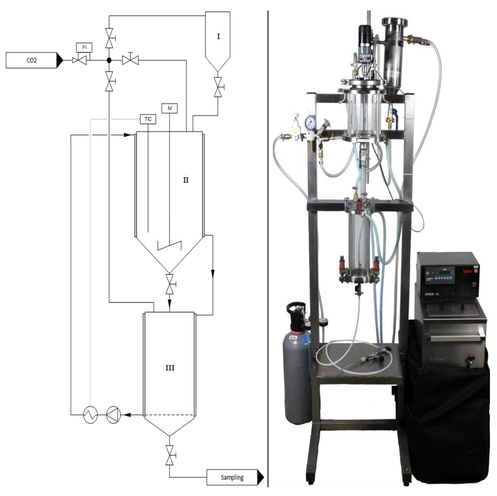
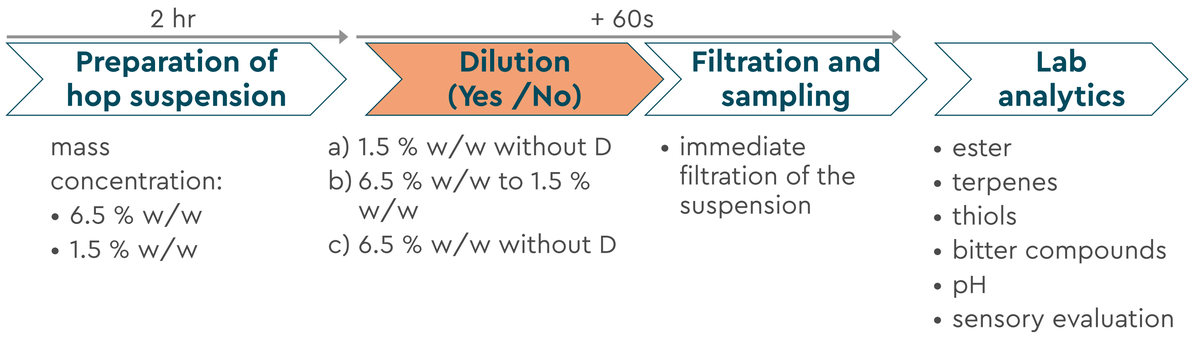


Fig. 3
Laboratory filter developed in-house, suitable for conducting highly reproducible dry hopping trials

The external extraction procedure was simulated with a temperature-controlled laboratory filtration apparatus capable of holding pressure (fig. 3). This consists of a dosing vessel (I) for accurately measuring the volume of beer, a dispersion vessel (II) for producing the hop suspension and a filtration vessel (III) for separating the particulate hop material from the beer.

As shown in the simplified flowchart of the procedure below, a suspension was prepared by adding 6.5 % w/w hops to the beer, which was then diluted (D) with the base beer and immediately filtered. Samples were collected under counterpressure and analyzed in the laboratory. For comparison, suspensions hopped to a concentration of 1.5 % w/w and 6.5 % w/w, respectively, without dilution, were analyzed as well.

Simplified experimental procedure:



Base beer: Bottom-fermented (lager) beer, produced without dry hopping, with 5.3 % ABV and 14 mg/l iso-α-acids

Hops: Citra® BBC Pure Hop Pellets

Results

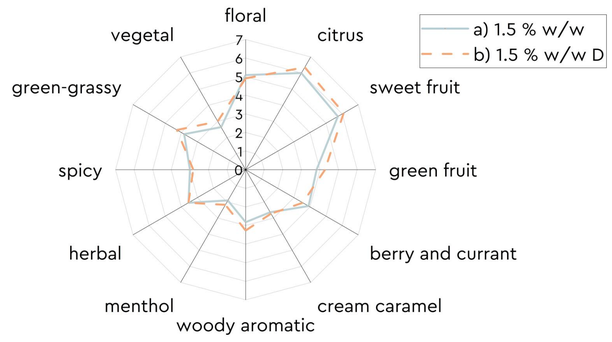


Fig. 4:
Sensory evaluation – hop aroma

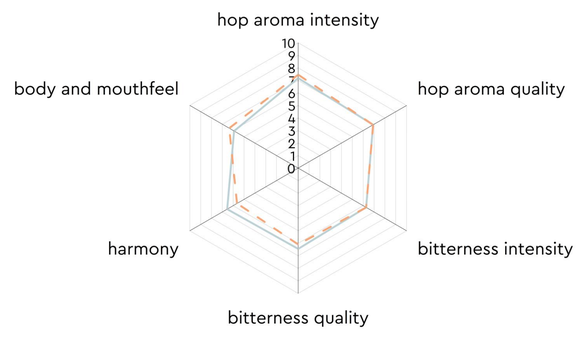


Fig. 5:
Sensory evaluation – hop bitterness

The discriminative test showed no significant difference between the new optimized method with dilution (1.5 % w/w D) and the traditional method (1.5 % w/w) up to a significance level of α=0.2. Also in the descriptive tasting, no perceptible difference (α=0.05) was found either for the aroma evaluation (fig. 4) or for the quality of the bitterness (fig. 5).

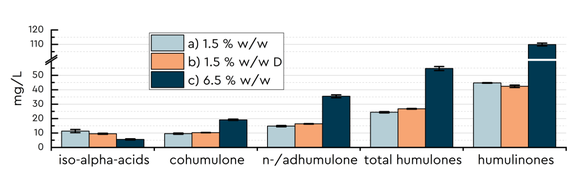


Fig. 6:
Analysis of hop bitter compounds

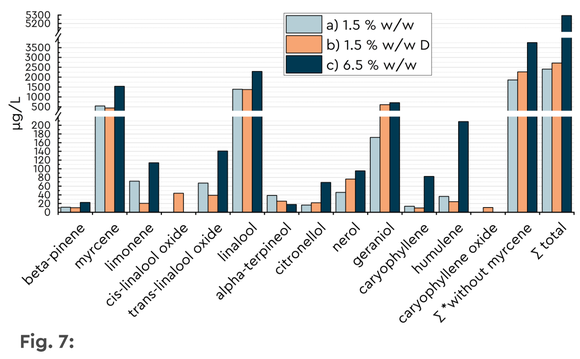


Fig. 7:
Analysis of hop terpenes

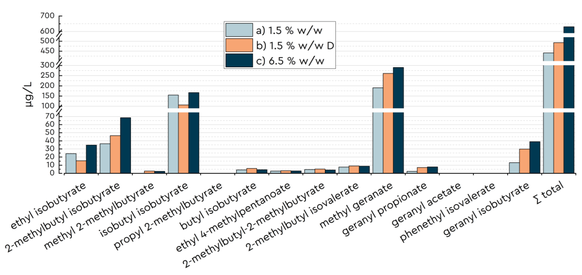


Fig. 8:
Analysis of hop esters

The 6.5 % w/w samples showed higher values in absolute figures, but not four times higher than might be expected based on the concentration added.

The extraction of both bitter (fig. 5) and aroma compounds (figs. 6, 7) is inhibited at higher mass concentrations of hops.

The dilution of the dry-hopped beer after 120 min of dispersion with a mass concentration of 6.5 % w/w caused an immediate resumption of mass transfer, both with the bitter and aroma compounds, within a very short contact time in the diluted state at 1.5 % w/w (< 60 s).

This shows that the inhibition of mass transfer can be lifted very quickly by lowering the mass concentration of the hops in the suspension, yielding similar results for mass transfer in a beer initially produced with hops at a concentration of 1.5 % w/w.

Conclusion

The results showed a significant deterioration in the transfer rates for many hop aroma compounds as a function of increasing quantities of hops added during dry hopping. The in-line dilution procedure, applied to recreate the ideal transfer conditions, was highly effective. It was demonstrated that this can restore and complete the mass transfer of hop compounds within a few seconds.

This makes it feasible to use completely new dry hopping techniques in which, for example, hop bitter and aroma compounds are extracted outside of the tank continuously and in the shortest possible time. Furthermore, the particulate matter from the hops (figs. 1, 2) can then be readily separated from the beer externally. This not only reduces tank occupancy times but also the levels of wastewater contamination. The spent hop material recovered from this procedure may also be suitable for reuse in the brewhouse due to its high residual alpha acid content.