# Dry hopping and turbidity

**QUANTITY AND TIMING** | There are many different categories of beer on today's global beer market, and consumers have certain expectations when they choose a particular type. Most dry-hopped beers are top-fermented e.g. (New England) India Pale Ales, and a certain turbidity is an essential part of these beers' character. To investigate how haze is affected by dry hopping, a study was conducted to evaluate the influence of pellet quantity and the time of dosage in the cold side of the brewing process.

**TODAY'S RECIPES** for dry-hopped beer styles vary in many ways: hop variety/varieties, quantity and type of hop product, dosing time and applied technique, to name just a few. In any case, imparting an intense and unique hop aroma is an essential part of producing these beer styles. A wide range of malts and other cereals are also used to influence and define the characteristic overall flavour. The interaction of hops and other raw materials strongly impacts the overall beer matrix including the turbidity after dry hopping. Another key factor is the ever-growing variety of yeast strains on the market, not exclusively when influencing aroma but also with regards to haze formation [4].

Dry-hopped beers are often sold unfiltered and consumers expect a certain haziness [5]. This non-biological turbidity is forced by interactions of haze-active proteins with polyphenols, as well as their particle size distribution [1, 3]. Once bottled, it is not uncommon for the beer's haze to change, reduce or become inhomogeneous over time. In some cases, sedimentation or coarse flocculation may even occur [2].

Two approaches were investigated to further understand the interaction of turbidity in traditionally dry-hopped beer using hop pellets:

- Trial quantity (TQ): varying the quantity of hop pellets while maintaining a constant dosing point and contact time;
- trial timing (TT): varying the time of dry hopping at a constant quantity and contact time.

The turbidity of the freshly brewed beer was analysed as well as the beer after it had been stored away from light and at ambient temperature for 6 months.

**Authors:** Mathis Geserer, Frank Peifer, Sandro Cocuzza, Simon H. Steiner Hopfen GmbH, Mainburg; Prof. Martin Krottenthaler, Weihenstephan-Triesdorf University of Applied Sciences, Bioengineering (Sciences) department, Brewing and Beverage Technology, Freising; Korbinian Schmid, Schneider Weisse G. Schneider & Sohn GmbH, Kelheim; Germany

## › Beer and hop recipe

Hop pellets of the variety US Cascade (crop 2021) were exclusively used for all trials. The base beer was produced according to Hopsteiner's Pale Ale recipe. The beer had an original gravity of 14 °Plato achieved with a grain bill consisting of 39% pilsner malt, 30% Vienna malt, 15% pale caramalt, 15% wheat malt and 1% acidulated malt. Mash-in temperature was 65 °C, which was kept constant for a 30 min rest, followed by heating up to 72 °C and a subsequent rest for 30 min. After achieving a positive iodine normality test, the wort was heated to 78 °C and transferred to the lauter tun. Wort boiling took 70 min. with an early kettle and a late hop addition (80/20% of alpha acids) to achieve 14 IBU before dry hopping. After boiling and a whirlpool rest, fermentation was conducted at atmospheric pressure and at 20 °C with the ale yeast strain S-04 in the form of dry yeast.

Two brews of this base beer were produced and used in the respective dry-hopping trials, each performed in triplicate and on an 18-litre pilot scale.

In the TQ trial, dry hopping was conducted in the middle of maturation, varying the hop rates in ascending steps of 250 g (fig.1, left). For the TT approach, the hopping rate was fixed at 750 g/hl while the dosage time was varied, within a range of 1 to 10 days after pitching the yeast (fig. 1, right). All beers in both TQ and TT were handled in exactly the same way aside from the single trial variation of dry hopping.

The unfiltered beers were filled in flint glass bottles for visual evaluation and turbidity analysis, and filled in regular brown

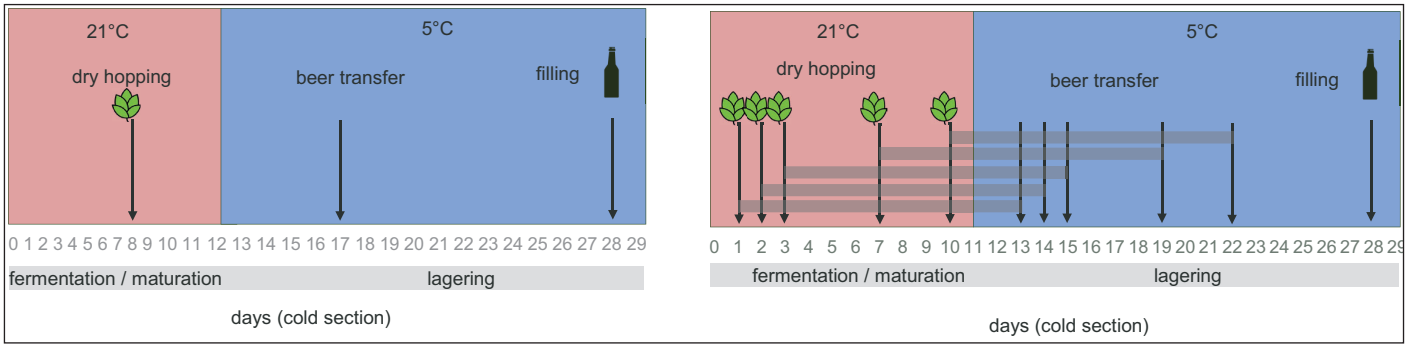


**Fig. 1 Overview of the dosage times; left: trial quantity (TQ); right: trial timing (TT)**

bottles for chemical and physical analysis. A turbidity meter was used to detect the light scattered by particles in the sample at two different angles. Particles below 1 µm can be detected at an angle of 90° and particles above 1 µm at an angle of about 25° forward scattering. [4]. Photos were also taken to visualise the beers' haze over time and the turbidity was analysed once the aged beers had been homogenised.

## › Results and discussion

### *Trial quantity (TQ)*

The average turbidity values for TQ are shown in fig. 2.

The initial turbidity in the fresh base beer was 54/76 EBC units (90°/25°). With more hops added, the pattern of the values for 25° and 90° remain highly comparable, which shows the turbidity-forming particles behave similarly irrespective of size. A dry-hopping dosage of 750 g/hl achieved values of 174/198 EBC (90°/25°). Turbidity analyses of beers that were dry-hopped with 1000 g/hl and more (not shown) exceeded 200 EBC units. Increasing hop dosages resulted in turbidity increases of 14/13 EBC units (90°/25°) for each 100 g pellets per hl added.

It can be concluded that the increase in haze is primarily due to the greater concentration of polyphenols and haze-active proteins introduced by dry hopping (table 1). On average, each 100 g/hl pellets added resulted in about 12.4 mg/l additional polyphenols. These compounds form com-

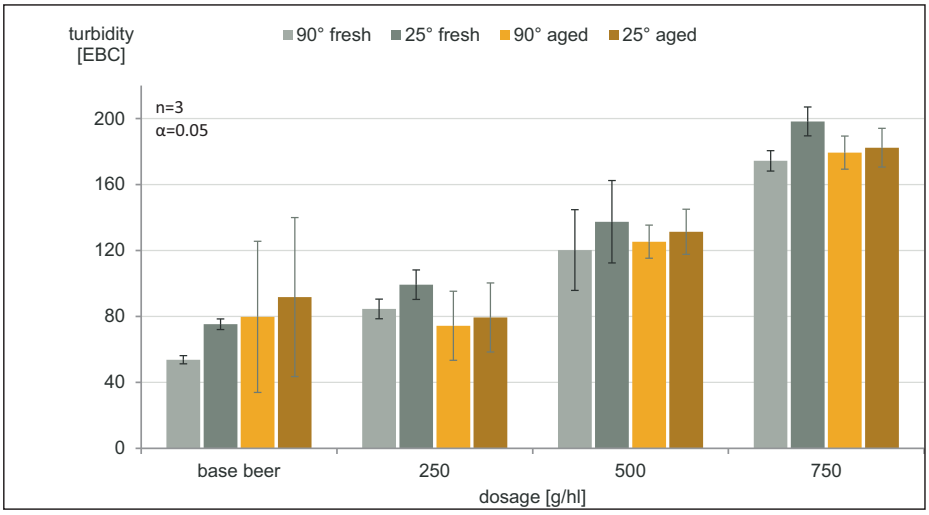


**Fig. 2 Turbidity values for trial quantity**

**Fig. 3 Trial quantity: fresh samples (left), 6 months at 20 °C, aged samples (right)**

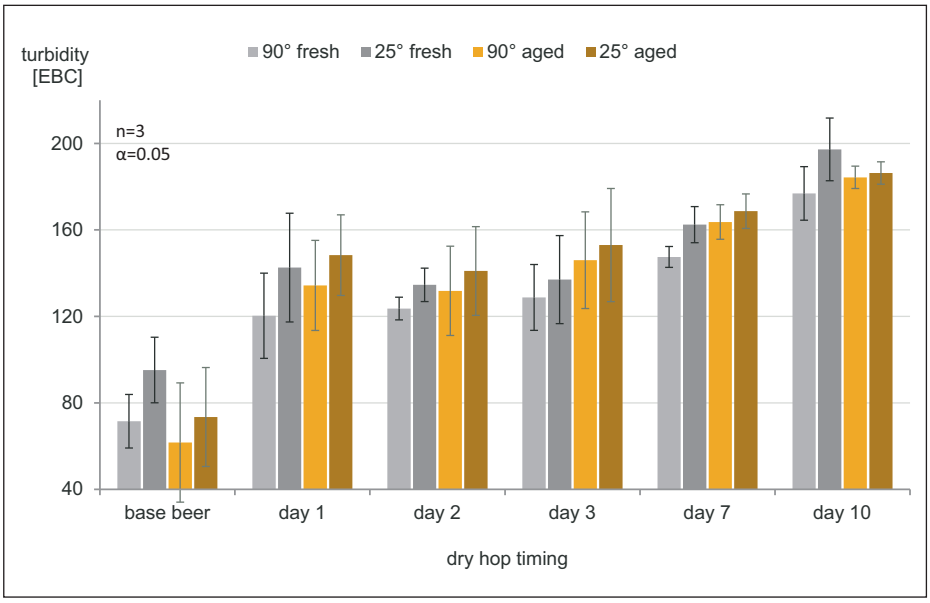


**Fig. 4 Turbidity values trial timing**

plexes that remain suspended in the beer, increasing light scattering and turbidity.

Turbidity analyses of the aged samples show very comparable results to the corresponding fresh samples (fig. 2). However, it must be noted that after 6 months of storage, the beer bottles were homogenised for standardisation purposes prior to analysis. The consistency of analysis results of 90°/25° of the aged samples compared to the fresh ones revealed no significant difference and indicates that the particle sizes and their distribution within the formed haze remain unchanged throughout the warm storage trial. However, particles do not remain suspended but settle over time and so visually, the samples change drastically when not moved. Pellet dosages of up to 500 g/hl form a visible supernatant, while dosage at 750 g/hl still produces a slight haziness (fig. 3).

## › Trial timing (TT)

The results are summarised in fig 3.

Compared to the base beer, dry hopping at 750 g/hl at different timings significantly impacted beer turbidity. The lowest turbidity was measured in the base beer at 72/95 EBC (90°/25°). The highest turbidity was observed for the dry-hop timing on day 10 at 177/197 EBC (90°/25°), resulting in a maximum delta of 105/102 EBC (90°/25°). The impact was lower for dosages during active fermentation/mid maturation (days 1 to 7) compared to the latest dry hopping on day 10. An average increase of 59/49 EBC (90°/25 °) was observed from days 1 to 7, with no significant difference between the individual timings. The increase in haze intensity with the latest dry hopping on day 10 suggests that reduced yeast activity at the end of fermentation allows more haze-active proteins and polyphenols to remain in suspension. Day 7 already indicates this tendency. Similar observations were made by Lacy, Burns et al [4].

Once again, the aged samples, when homogenised, show highly comparable analysis results to the fresh samples (fig. 4).

When the samples are unmoved, their visual appearance changes over time. The haze settles and leaves clearly visible supernatants in most samples. The settled samples appear to be hazier, the later that dry hopping takes place. This becomes especially obvious with the sample dry hopped on day 10 (fig. 5).

## › Conclusion

Gradually increasing dosing rates for dry hopping as well as varying the timings of adding Type 90 pellets during fermentation and maturation were investigated with regard to their impact on the turbidity of the finished beer. Each beer was additionally stored at 20 °C for 6 months and analysed and visually examined. The study revealed several effects of dry hopping with pellets on the turbidity of the produced beers:

1. Incremental dosing rates correlate well with higher turbidity. In this case, the corresponding higher contents of polyphenols introduced could be the main reason.
2. The timing of dry hopping during fermentation and maturation also impacts the turbidity. This effect is greater when dry hopping occurs later in the process, especially once fermentation is complete.

All observations are independent of particle size, as turbidity increases at both

**Fig. 5 Trial timing: fresh samples (left), samples aged for 6 months at 20 °C (right)**

## POLYPHENOL CONCENTRATION IN TRIAL QUANTITY

| Dry hop dosage pellets T90 | Base beer (0 g/hl) | 250 g/hl | 500 g/hl | 750 g/hl |
|---|---|---|---|---|
| Polyphenols [mg/l] | 191 ± 7 | 203 ± 24 | 235 ± 26 | 284 ± 41 |

*Table 1*

25° and 90° in a very similar way the more hops added and the later the dry hop timing. Visual appearance clearly changes over time if the bottles are not moved, as seen in the pictures of the flint bottles (fig. 3 and 5). After homogenising the formed sediments, there are no major differences between the turbidity of fresh and stored samples. This also applies to both trials performed (quantity and timing).

The results of this study indicate that the turbidity of dry-hopped beer clears up over time during storage, and the settled particles do not agglomerate or demonstrate significant changes in their particle size distribution. However, the initial turbidity of a traditionally dry-hopped beer with pellets is strongly influenced by the amount and time of dry hopping during production.

For a more detailed and in-depth presentation of this study, please read the BrewingScience article "How the amount and timing of dry hopping affects beer turbidity" (BrewingScience vol. 77, July/August 2024, pp. 66-75). ■

### › References


1. Benucci, I.; Mazzocchi, C.; Lombardelli, C.; Esti, M.: "Phenolic- Degrading Enzymes: Effect on Haze Active Phenols and Chill Haze in India Pale Ale Beer", Foods, 12, 2023, p. 77.
2. Dangl, S.; Schüll, F.: "Dry-hopped beers: Colloidal stability and resistance to aging", BRAUWELT International, no. 3, 2016, pp. 183–185.
3. Englmann, J.; Jacob, F.; Ilberg, V.; Tietze, J.: "Vergröberung erwünscht – Einfluss der Kurzzeiterhitzung auf die Trübungsstabilität von Weißbier", Brauindustrie, no. 8, 2021, pp. 16–19.
4. Lacy, K.; Burns, L.: "Identification of the Yeast Mannoprotein Gene HZY1 as a Key Genetic Determinant for yeast-derived Haze in Beer", www.biorxiv.org/content/10.1101/2023.07.10.548400v1.full, accessed on 18 March 2025.
5. Mastanjević, K.; Krstanović, V.; Lukinac, J.; Jukić, M.; Vulin Z.: "Beer – The Importance of Colloidal Stability (Non-Biological Haze)", Fermentation, Nr. 4(4), 2018, S. 91.
6. MEBAK online, Method B-420.01.272: Haze – Measuring Device. Rev. 2022-05, Mitteleuropäische Brautechnische Analysenkommission e.V., Freising, www.mebak.org/en/methode/b-420-01-272/haze-measuring-device/2801, accessed on 18 March 2025.