Everything under control? Dry hopping and chemical-physical properties of beer

QUALITY ASSURANCE | Dry hopping has become an essential technique in beer brewing, designed to create the aroma of a beer and to produce pronounced, typical beer styles. This excerpt from an extensive research project provides some insight into the chemi-cal-physical changes associated with dry hopping.

WHEREAS MAINLY THE AROMA of a beer should be influenced by dry hopping, other accompanying changes such as, for example, the composition of bitter substances [1, 2], pH value [3–5], extract and alcohol content [6] or also foam stability [7–9] are given little attention. Depending on dosing and intensity of hopping in the cold section, significant changes compared to the beer before dry hopping may occur. Therefore, not only optical quality characteristics, such as foam stability, which is immediately recognizable to the consumer, should be the focus of production, along with sensory characteristics. Changes in alcohol content or pH may directly impact the declaration on the label and/or the beer's microbiological stability. In this study, the influence of dry hopping on chemical-physical properties of a beer was investigated. Results are shown in the figures including a trendline for better readability.

Brewing tests

To study the influence on selected beer attributes after dry hopping, a base beer (Pale Ale) was produced in the pilot brewery of Simon H. Steiner, Hopfen, GmbH (Hopsteiner), Mainburg on a 6 hl scale. After main fermentation at 18 °C using the yeast strain TUM 540, all tests were carried out in triplicate under standardised conditions. The identical base beer was divided into 20 l NC kegs and statically dry hopped with US Cascade pellets type 90 in increasing amounts up to 1500 g/hl for one week. Hops were subsequently removed and the resultant beer was stored for another two weeks at 2 °C before being examined. Table 1 lists the analytical data of the hop pellets used.

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Behaviour of bitter substances

Concentration of α-acids, iso-α-acids and humulinones in beer was analysed according to Analytica-EBC 9.47 (modified) and the bittering units (BU) according to Analytica-EBC 9.8 [10]. Fig. 1 shows the analysis results as a function of dosage of pellets type 90 in the cold section.

As expected, α-acids as well as humulinones increase in line with the amounts of hops added. Iso-α-acids dropped continuously. It should be noted that, the lower the amount of hop pellets added, the higher loss will be. When only 250 g/hl are added, initial concentration drops from 54.0 mg/l to 48.2 mg/l, equalling about ten per cent. At a six times higher pellet addition of ultimately 1500 g/hl, only 61 per cent of the initial concentration of iso-α-acids remain in the dry hopped beer. On average, the iso-α-acid concentration decreases by 2.3 mg/l per 100 g/hl pellets added in this test series. Based on the amounts of α-acids and humulinones in the pellets, the latter increased considerably (on average 1.0 mg/l per 100 g/hl P90), this had been expected. Only less than ten per cent of the poorly soluble α-acids found their way into the beer. In further trials of this study, the loss of iso-α-acids was associated with plant material of the hop pellets precipitated after main fermentation [11]. In this test series, bittering units were almost constant (71.5–76.0 BU), showing no clear trend, although other studies suggested an increase. It is a known fact when determining bitterness units, other bitter substances such as α-acids and also humulinones do analytically contribute to a certain extent and thus – at least partially – compensate the decline in iso-α-acids [1, 2]. [1, 2]. Though no clear explanation can be provided for the relatively constant bitter-

ANALYSIS OF HOP PELLETS

	Method [10]	Pellets type 90
Variety (year)		US Cascade (2016)
α-acids	EBC 7.7*	5.0 %
Humulinones	EBC 7.7*	0.3 %

** the most recent international standards were used for the calibration*

Table 1

ness units here, it is nevertheless obvious that BU analyses cannot be used for a qualitative statement about the spectrum of bitter substances in dry hopped beers.

Dry hopping and pH value

Fig. 2 shows the influence of dry hopping on pH value of beer according to Mebak 2.13 [12].

Despite the rather high initial pH of 4.9 measured in the not dry hopped base beer, the hop dosages resulted in a very consistent increase of 0.03 pH units for every 100 g/hl added. This development confirms other research studies which also reported increases in pH in similar ranges [3–5]. As Brenner et al. [13] concluded that a higher pH negatively impacts quality of beer bitterness (harsh, lingering), such change should be taken into account when producing dry hopped beers. A higher pH value may also have an unfavourable effect on microbiological stability of beer [14]. Again, some increases in the pH values found in further tests of this study might possibly be attributed to the plant material used.

Real extract and alcohol level

The real extract covers any soluble substance which contributes to the density of the beer. By adding hop pellets to beer, many soluble substances dissolve in the beer and increase this value. Hops also introduce hydrolysing enzymes resulting in the so-called Hop Creep effect [15]. In this instance, beer dextrins are enzymatically split and substrates are formed that can be metabolised further by yeast [6]. As a consequence, alcohol and CO_2 may be formed again. Whether this is the case or how much will be formed depends on various factors such as hop variety and batch, yeast activity and vitality, cell count or amounts of pellets added. The subsequent utilisation of fermentable substrates can also be controlled by temperature. In the tests described here, the beer which was stored at 2 °C and almost fully fermented, was dry hopped, resulting in hardly any yeast or enzyme activity. The increase in alcohol shown in fig. 3 is thus relatively low, in especially in view of the significant increase in real extract content.

Particular precautions are required when producing dry hopped beer with bottle fermentation. When disregarding the above-described effect, problems such as an excessively high bottle pressure and, consequently, a higher propensity to gushing cannot be excluded. In the worst case, customers are at risk of being injured by exploding containers.

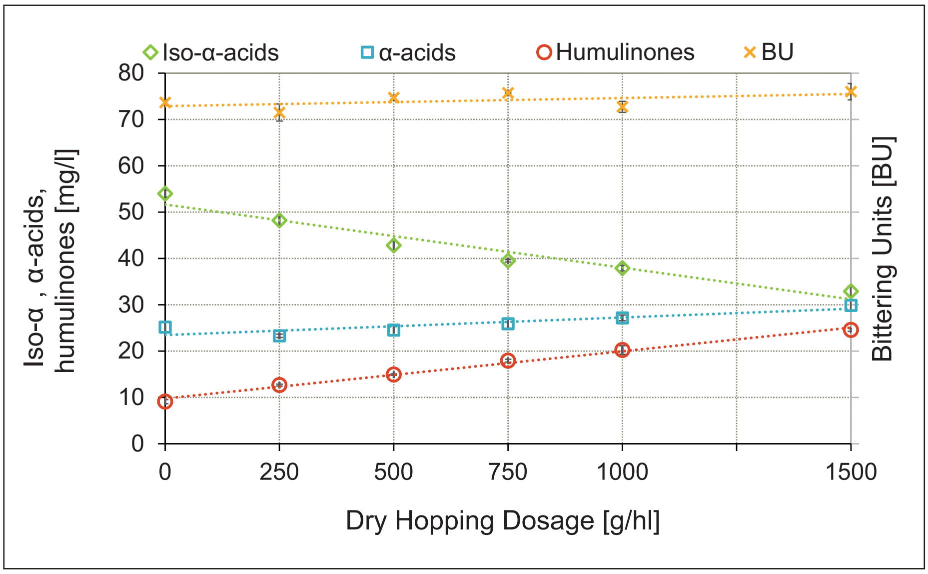

Fig. 1 Bitter substances and BU after dry hopping

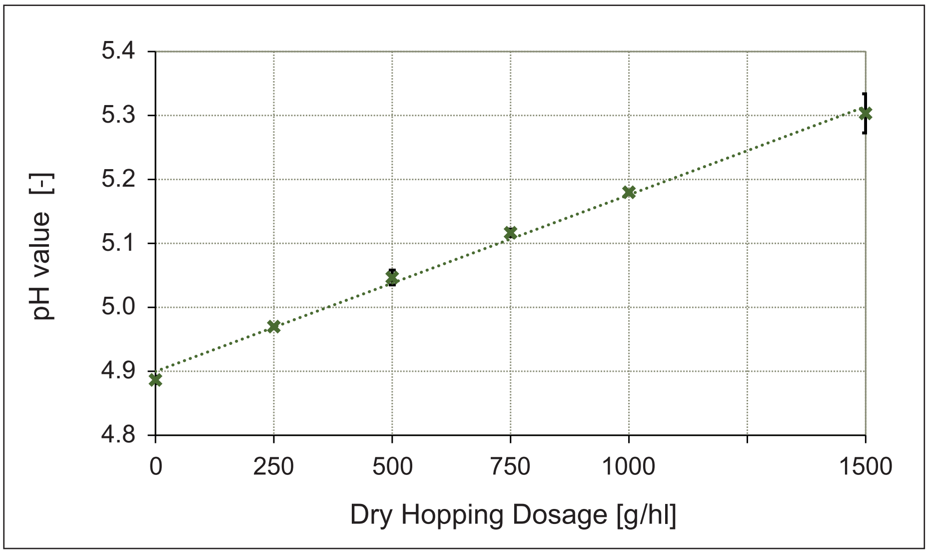

Fig. 2 pH value after dry hopping

Beer foam

Foam stability of all beers in this test series was analysed using two different foam measurement methods. One of them was NIBEM in accordance with Mebak 2.18.2, the other one the Steinfurth Foam Stability Test in accordance with Mebak 2.18.4 [12]. Fig. 4 shows the results.

Current publications do not provide a clear indication about the influence of dry hopping on foam stability. After dry hopping, both a deterioration and an improvement of foam stability were observed [7–9]. In this test series, both methods indicated a decreasing trend though the indices as such still point to good foam stability with extreme hop additions of 1500 g/hl. On average, stability according to NIBEM dropped 10.8 seconds per 100 g/hl of pellets added, and the Half Life Time according to Steinfurth 1.2 seconds.

Summary

Dry hopping changes some chemical-physical properties of beer. In terms of composition of bitter substances, a drop in iso-α-acids should be expected. In contrast, the concentration of α-acids and humulinones increase. Both changes have a different impact on analytical determination of bitterness units. In addition to changes in compositions of bitter substances, particular focus during production should be laid on a rise in pH value and, if applicable, on a higher

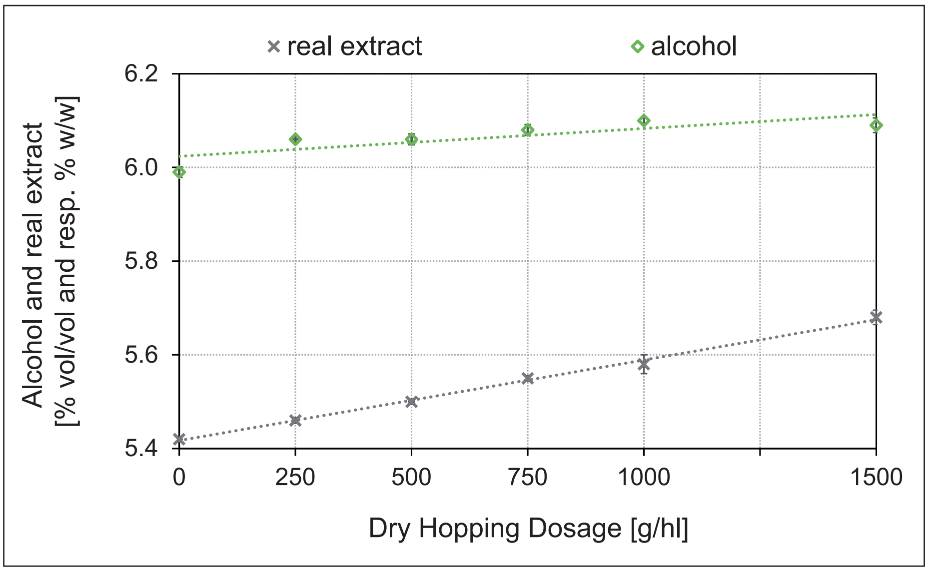

Fig. 3 Real extract and alcohol content according to MEBAK 2.9.6.3 [12] after dry hopping

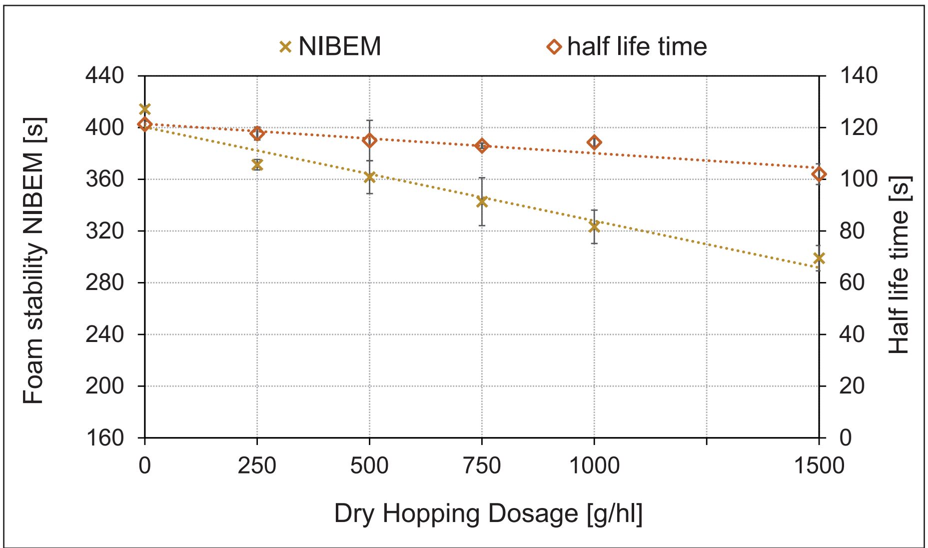

Fig. 4 Foam stability after dry hopping

alcohol and CO_2 content. The latter may result in complaints and jeopardise the safety of consumers. You will find further results from this research project (e.g. influence of hop plant material) in the archives of BrewingScience [11]. ■

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References

1. Parkin, E.; Shellhammer, T.: "Toward Understanding the Bitterness of Dry-Hopped Beer"; Journal of the American Society of Brewing Chemists 75 (4), 2017, pp. 363–368.
2. Maye, J. P.; Smith, R.: "Dry Hopping and Its Effects on the International Bitterness Unit Test and Beer Bitterness"; Master Brewers Association of the Americas, 53, no. 3, 2016, pp. 134–136.
3. Lafontaine, S.; Shellhammer, T.: "Impact of static dry-hopping rate on the sensory and analytical profiles of beer", Journal of the Institute of Brewing, 124, no. 4, 2018, pp. 434–442.
4. Maye, J. P.; Smith, R.; Leker, J. S.: "Humulinone Formation in Hops and Hop Pellets and Its Implications for Dry Hopped Beers", Master Brewers Association of the Americas, 53, no. 1, 2016, pp. 23–27.
5. Oladokun, O.; James, S.; Cowley, T.; Smart, K.; Hort, J.; Cook, D.: "Dry-hopping: The Effects of Temperature and Hop Variety on the Bittering Profiles and Properties of Resultant Beers", BrewingScience vol. 70, no. 11/12, 2017, pp. 187–196.
6. Kirkpatrick, K. R.; Shellhammer, T. H.: "Evidence of Dextrin Hydrolyzing Enzymes in Cascade Hops (Humulus lupulus)", J. Agric. Food Chem. 66 (34), 2018, pp. 9121–9126.
7. Maye, J. P., Smith; R.; Leker, J.: "Dry Hopping and Its Effect on Beer Foam"; BRAUWELT International no. 2, 2018, pp. 93-95.
8. Kaltner, D.; Forster, C.; Flieher, M.; Nielsen, T. P.: "The influence of dry hopping on three different beer styles"; BRAUWELT International, no. 6, 2013, pp. 355–359.
9. Reichlmayr-Lais, A. M.; Steinhaus, M.; Methner, F.-J.; Seewald, T.: "Schlüsselaromastoffe der neuen deutschen Hopfensorten Hallertau Blanc, Hüll Melon, Mandarina Bavaria und Polaris und ihr Einfluss auf das Aroma hopfenbetonter Biere in Abhängigkeit von der Technologie der Hopfengabe"; AiF 18069 N – final report, 2017.
10. n.p.: "Analytica- EBC", ed. European Brewery Convention, https://brewup.eu/ebc-analytica (accessed on 19 May 2020).
11. Cocuzza, S.; Zarnkow, M.; Stallforth A.; Peifer, F.; Jacob, F.: "The impact of dry hopping on selected physical and chemical attributes of beer"; BrewingScience, vol. 72, 2019, pp. 118–124.
12. n.p.: "Wort, Beer and Beer-based Beverages (WBBM)"; ed.: Mebak, 2013, https://www.mebak.org/en/the-mebak-collection-of-brewing-analysis-methods/mebak-wort-beer-and-beer-based-beverages.html (accessed on 19 May 2020).
13. Brenner, M. W.; Vigilante, C.; Owades, J. L.: "A Study of Hop Bitters (Isohumulones) in Beer"; Proceedings of the American Society of Brewing Chemists 14, 1956, pp. 48–61.
14. Simpson, W. J.: "Studies on the sensitivity of lactic acid bacteria to the hop bitter acids", Journal of the Institute of Brewing, 99, no. 5, 1993, pp. 405–411.
15. Kirkpatrick, K. R.; Shellhammer, T. H.: "A Cultivar-Based Screening of Hops for Dextrin Degrading Enzymatic Potential", Journal of the American Society of Brewing Chemists, vol. 76, 2019, pp. 247–256.