10TH TRENDS IN BREWING
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ANALYTICAL AND SENSORY ASSESSMENT OF THE FLAVOUR STABILITY IMPACT OF DRY-HOPPING IN SINGLE-HOP BEERS

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INTRODUCTION

Dry-hopping is a technique which is increasingly being applied in the production of specialty beers in order to impart additional and plant-original hoppy aroma notes. However, its impact on the flavour stability of beers is currently not well understood, especially regarding the specific contribution of the hop variety used. In this study, the flavour stability of a series of six single-hop beers derived from three distinctly different commercial hop varieties (A, B, C) was investigated.

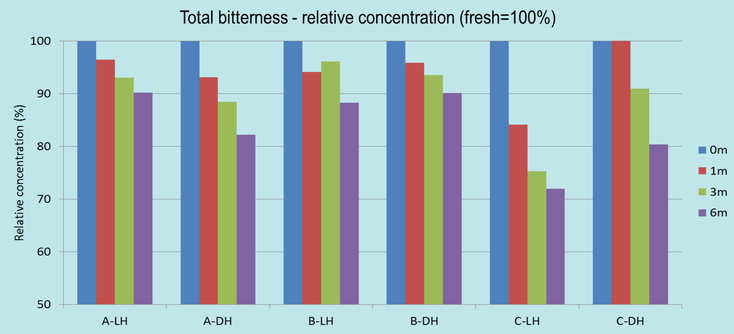
METHODOLOGY

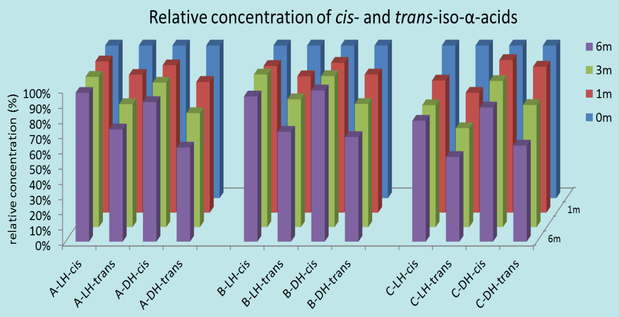
All beers were brewed and bottled on a semi-industrial scale (40 hl), and each beer was considered both before (late-hopped - LH) and after an additional dry-hopping step (dry-hopped - DH). The beers were immediately stored at 0°C to preserve freshness. For the evaluation of flavour stability, samples were aged in the dark at 25°C for 1, 3 and 6 months. Semi-quantitative determinations of hop oil-derived constituents were performed using HS-SPME in combination with GC-quadrupole MS operating in the selected ion-monitoring mode. Staling aldehydes in all beers were quantitatively determined using HS-SPME in combination with on-fibre PFBOA derivatisation and GC-MS. Quantitative determinations of the beer bitter acids were carried out through direct injection of the beer samples (in-house UPLC procedure). Sensory evaluation of flavour deterioration was performed by a trained panel (8 panellists), who were asked to give overall-ageing-scores (OAS: 0=not aged; 2=very lightly aged; 4=lightly aged; 6=clearly aged; 8=strongly aged/undrinkable) as well as to indicate a personal preference between the late- and the dry-hopped beer samples aged for 6 months.

ISO-α-ACIDS

- During ageing, a decline in total bitterness was observed for all the beers.

- As expected, *cis*-iso-α-acids were more stable than *trans*-iso-α-acids in all beers.

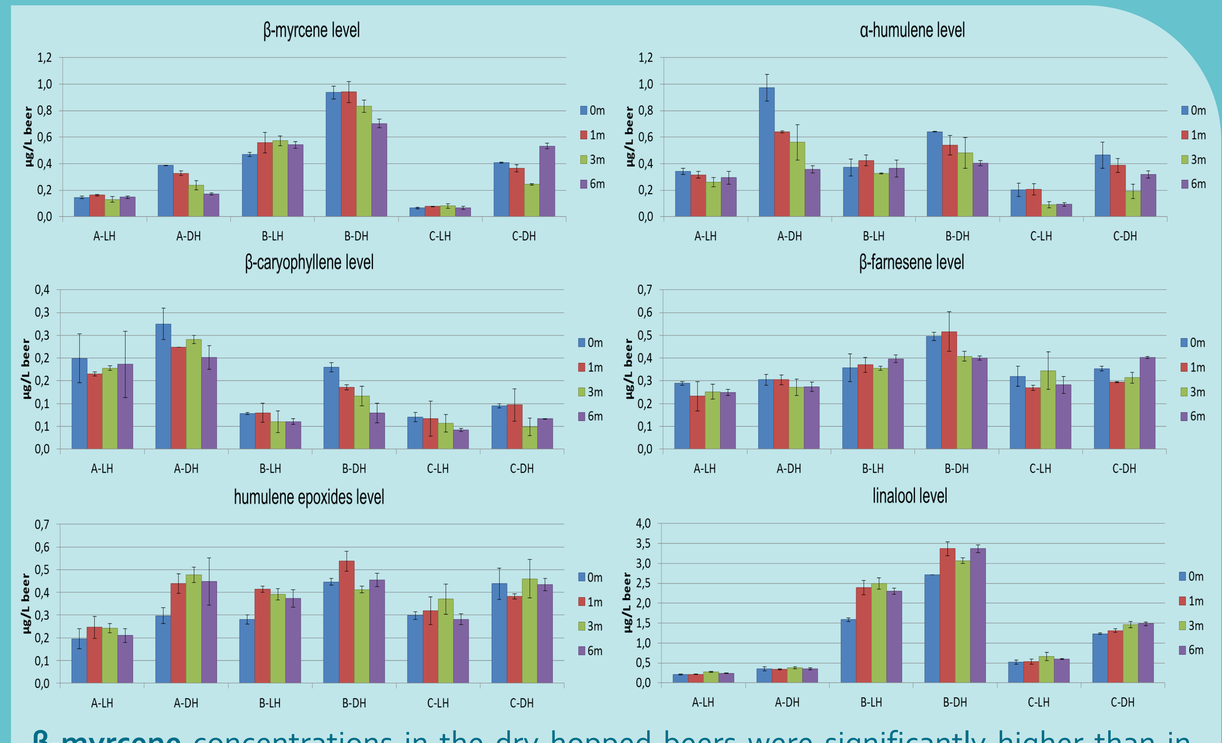




The decline in total bitterness was different **depending on LH versus DH**, but also depending **on the applied hop variety**:

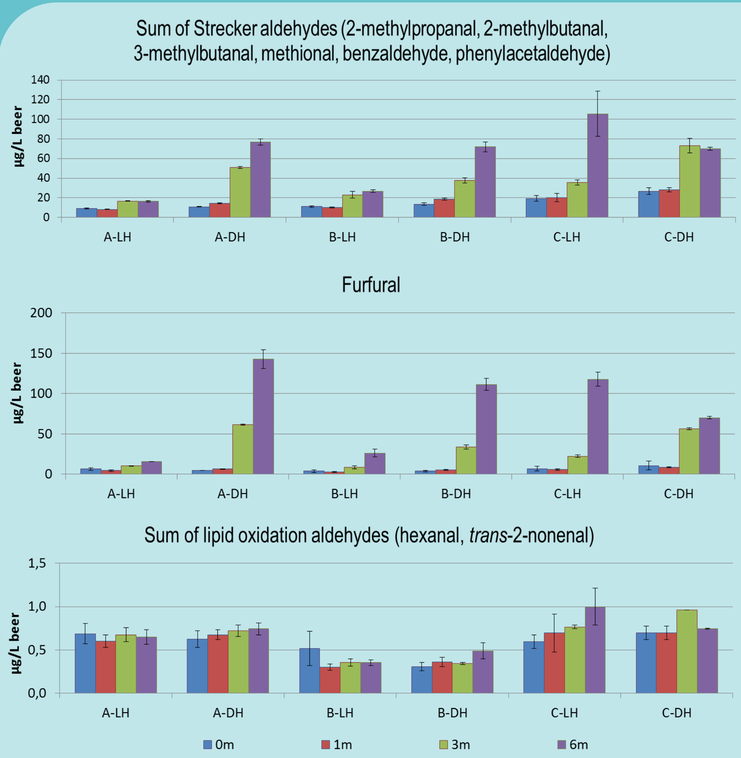
A: LH > DH
B: LH ≈ DH
C: LH < DH

HOP OIL-DERIVED CONSTITUENTS



β-myrcene concentrations in the dry-hopped beers were significantly higher than in the late-hopped beers and tended to **decrease with ageing**, whereas they remained fairly constant in the late-hopped beers. Similar behaviour could be observed for **α-humulene and β-caryophyllene**, while β-farnesene remained fairly constant during ageing regardless of the hopping regime. The sum of humulene epoxides I, II and III was found to be slightly higher in the dry-hopped beers, and did not change significantly during ageing. The amount of **linalool** in all beers appeared to **increase with ageing**, which has been attributed to the liberation of glycosidically bound linalool, according to the literature . After liberation from hop glycosides, linalool may contribute to the hoppy aroma of beer.

STALING ALDEHYDES



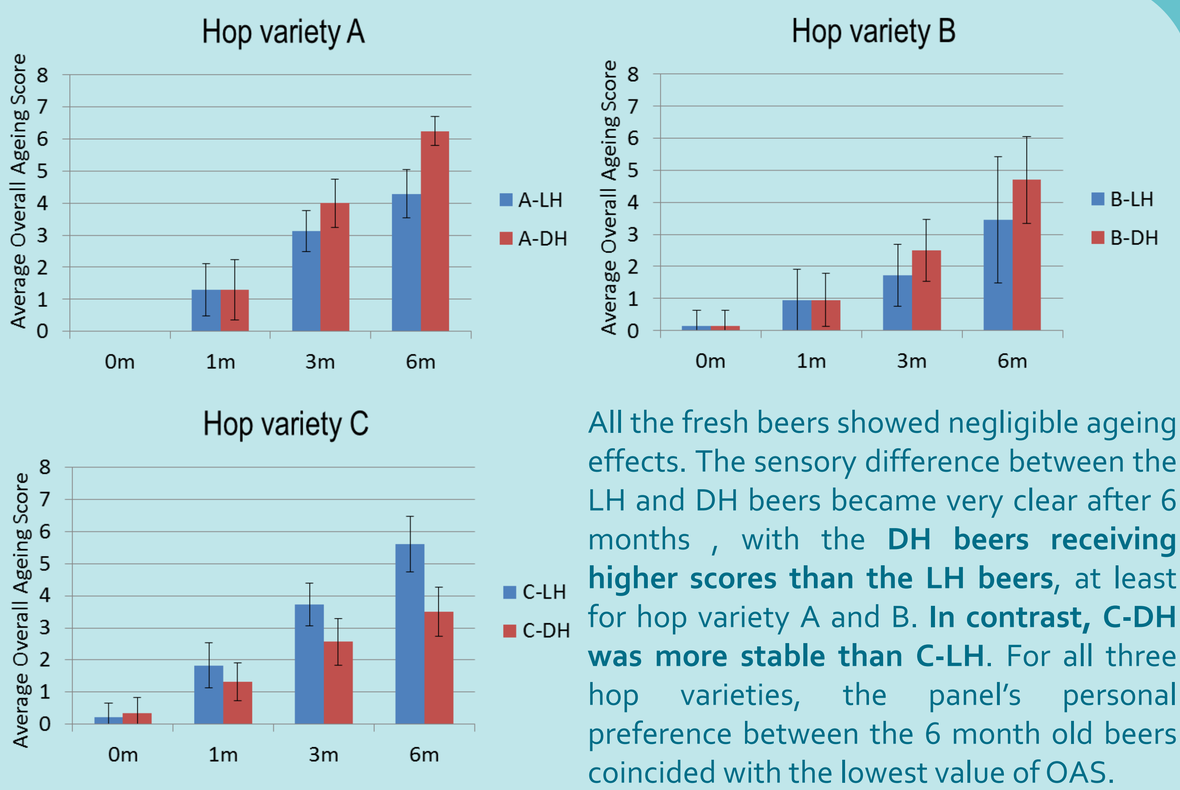
Aldehydes were observed to **increase with ageing time**.

After 6 months, **Strecker aldehydes** and **furfural** levels were **much higher for the DH beers**, with the exception of hop variety C.

Beer **C-LH** showed a significantly **higher increase than beer C-DH**.

The lipid oxidation aldehydes on the other hand, did not exhibit this trend, although C-LH did show a modest increase.

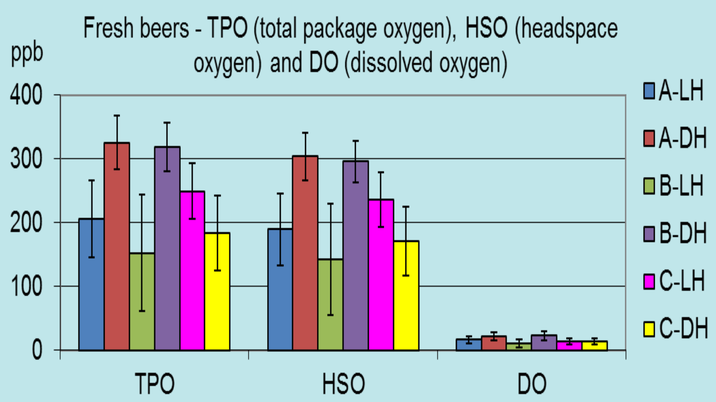
SENSORY EVALUATION



All the fresh beers showed negligible ageing effects. The sensory difference between the LH and DH beers became very clear after 6 months , with the **DH beers receiving higher scores than the LH beers**, at least for hop variety A and B. **In contrast, C-DH was more stable than C-LH**. For all three hop varieties, the panel's personal preference between the 6 month old beers coincided with the lowest value of OAS.

OXYGEN

DO and HSO were found to be lower in the LH beers for varieties A and B. For variety C, DO was comparable between the LH and DH beers, but HSO showed the lowest values for the dry-hopped beer. This may explain the difference in bitterness stability observed for hop variety C.



CONCLUSION

The above data suggest that the impact of an additional dry-hopping step on single-hop beer flavour stability is cultivar-dependent. The interplay of the degradation of iso-α-acids and hop oil-derived constituents on the one hand and the formation of staling aldehydes on the other hand is obviously a very intricate issue. However, the sensory results clearly reflect the analytical data. Whether oxygen content plays a significant role in the observed analytical and sensory changes upon ageing is unclear, but in any case, the dry-hopped beer C shows a markedly enhanced sensorial flavour stability compared to the other dry-hopped beers. Further research is needed in order to confirm these observations and to elucidate the possible underlying (bio-)chemical reasons for these interesting findings.

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