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WORLD BREWING CONGRESS 2016

Sensory Thresholds of Hop Volatile Compounds in Beer

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World Brewing Congress
August 13-17, 2016
Sheraton Downtown Denver
Denver, CO 80202, U.S.A.

Introduction

The authors hypothesized that high alcohol (>5% ABV) beer styles have the potential to impact sensory orthonasal detection threshold values of hop aroma compounds in a model beer system due to the solvating properties of ethanol. Published threshold values in "beer" have nearly always been carried out in pale adjunct-containing lagers of 5% alcohol by volume (ABV) or less. Literature values do not cover the hop forward styles or variants found in the craft beer sector, especially the highly hopped and higher ethanol, all-malt beers, that are upwards of 10% ABV.

To investigate hop flavor in beer, sensory detection thresholds have historically been used to screen odor-active compounds, since only a fraction of the hundreds of chemical compounds found in hop oil contribute to beer flavor. A compound's odor activity value (OAV) is the concentration of that compound in a food system divided by its sensory threshold concentration in the same system. Physiological and psychological variation of individual assessors impact group threshold values. Additionally, the food system (air, water, beer) in which the compounds are tested has been shown to impact group threshold values. The results of this study can be used for OAV calculations across a wide range of ethanol concentrations in beer.

Materials and Methods

To investigate the effect of ethanol content, ten potential character-impact or otherwise important hop compounds were selected to represent a range of chemical classes: (-)-β-carophyllene, (±)-β-citronellol, β-damascenone, geraniol, geranyl acetate, α-humulene, (±)-β-linalool, β-myrcene, nerol and 4-mercapto-4-methylpentane-2-one (4MMP).

Sample Preparation:

- Chemical standards (≥95% purity) were obtained from Sigma-Aldrich or Acros Organics
- Unhopped pale ale was brewed and fermented by a commercial brewery in Portland, OR
  - OG 10.9°P, BU 15.4 (iso extract), RE 3.82 (%w/w), ABV 4.63 (%v/v), pH 4.34, SRM 6.2
- At Oregon State University (OSU), ethanol content was adjusted to 5% ABV and 10% ABV while maintaining equivalent residual extract concentrations.
  - "5% ABV" – RE 3.59 (%w/w), ABV 4.88 (%v/v)
  - "10% ABV" – RE 3.59 (%w/w), ABV 9.30 (%v/v)

Sensory Evaluation:

- ASTM E679 methodology for group sensory orthonasal detection thresholds
- Assessor pool (29 males and 9 females) between the ages of 21 and 55 (32 average)
- Trained to testing methodology and were provided a reference (3x published threshold) with the identity and sensory descriptions of compounds prior to assessments
- Eleven testing sessions with nerol being tested twice, in the first and last session, to observe potential training/learning effects

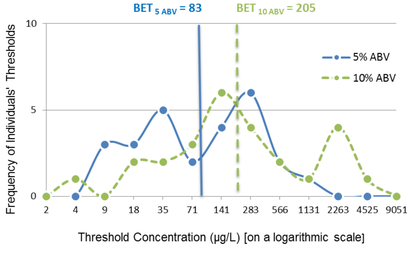
Results and Discussion

Table 1. Paired t-test of Hop Aroma Thresholds

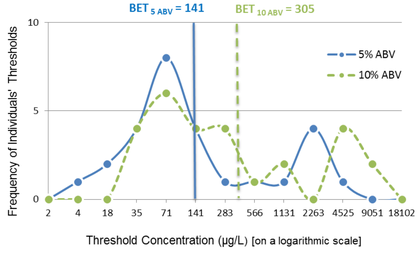
Compound	Group BET 5% ABV (ppb)	Group BET 10% ABV (ppb)	BET Diff 10% / 5% (ppb)	Paired t-test p-Value
Nerol (first)	975	1414	+1.5	>0.05*
Carophyllene	770	660	-1.2	0.97
Nerol (last)	632	453	-1.4	0.16
Geranyl Acetate	449	510	+1.1	0.32
Humulene	310	323	+1.0	0.44
Damascenone	**177**	**141**	-1.3	<0.00***
Linalool	**83**	**205**	+2.5	0.03**
Geraniol	**141**	**305**	+2.2	0.04**
Myrcene	195	74	-2.6	0.08*
Citronellol	53	31	-1.7	0.57
4MMP	0.005	0.007	+1.4	0.62

***denotes highly significant at p<0.001, ** significant at p<0.05, and *borderline significance at p<0.1

To investigate ethanol effect, paired t-tests were performed on each compound (Table 1). In the paired t-test design each assessor evaluated the stimulus in both the 5% ABV and 10% bases within the same session thereby serving as their own control. The majority (7/10) compounds were not influenced by ethanol concentration. Ethanol had a statistically significant effect on the threshold concentrations of β-damascenone (177 µg/L in 5% ABV to 141 µg/L in 10% ABV) but the practical significance of the 36 ppb difference between the two ethanol contents is uncertain. The threshold concentrations of linalool and geraniol significantly increased when more ethanol was present from 83 µg/L to 205 µg/L and 141µg/L to 305 µg/L, respectively (Graphs 1 and 2). Geraniol was the only hop compound featuring a bimodal distribution in both beer matrices supporting similar results found in previous studies (Graph 2).



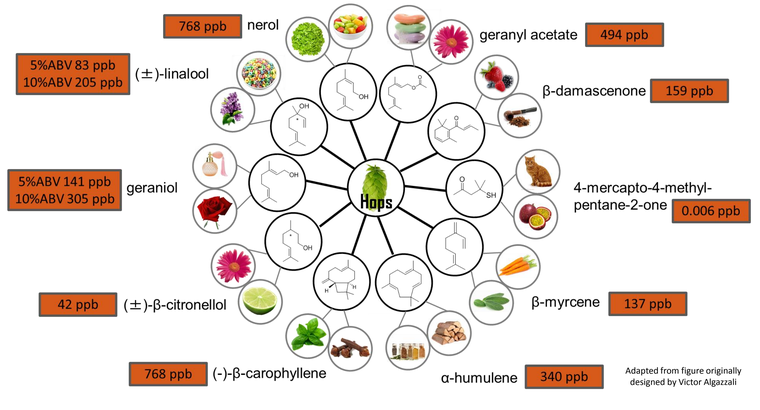
Graph 1. Distribution of individuals' thresholds for linalool



Graph 2. Distribution of individuals' thresholds for geraniol

The difference due to ethanol concentration for any compound is 1 or 2 scale steps or less than 3 fold differences in threshold value, whereas individuals' threshold values range across 9-11 scale steps or more than 250 up to 2,000 fold differences in threshold values. An individual's detection threshold is the lowest concentration of a chemical compound that is perceived by that individual. In practice, there is not a fixed boundary between non-perception and detection. An individual's age, genetics and general health as well as the individual's history of exposure to a stimulus will affect perception. Individuals with a normal sense of smell may vary in sensitivity to a stimulus by 1,000 to 10,000 fold and published group threshold values for a given stimulus are highly variable from one sensory panel to another, often varying by a factor of more than 100 fold. While ethanol concentration difference of 5% ABV clearly has an effect on overall beer flavor, its effect on sensory detection threshold of hop compounds is minor.

Thresholds of hop aroma compounds.



In conclusion, ethanol content has little effect on the sensory orthonasal detection thresholds of hop compounds in beer. The potential ethanol suppression of linalool and geraniol was relatively small, 2.5 fold, and would likely have little impact on the odor activity value of each.

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