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Effect of ethanol content on sensory aroma detection thresholds of hop compounds in water and beer

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Introduction

Hops are the spice of beer, contributing substantial impact per weight in the brewing recipe. Many approaches have been taken over the years to identify 'hoppy' character in beer. The identification of compounds that significantly contribute to the aroma of beer is commonly accomplished by the determination of odor activity values (OAV), which are defined as the concentration of a particular compound relative to its sensory threshold in the same beer or matrix. Historically, published thresholds have been measured in water or light lagers. And in many cases thresholds for individual hop compounds are not found in the published literature. Furthermore, the effects of different beer matrices, specifically alcohol concentration and beer style, on the sensory thresholds of hop compounds have not been quantified. This study evaluated the effect of ethanol (5%, 10%, 15% ABV) content and beer base (lager, brown ale) on a selection of important aromatic hop compounds; carophyllene, citronellol, damascenone, geraniol, geranyl acetate, humulene, linalool, myrcene and nerol. This information can be used by brewing scientists to define correct odor activity values for a range of different beer styles.

Materials and Methods

Chemical Standards: Obtained from Sigma-Aldrich or Fisher Scientific and were stated to have ≥95% purity. Stock solutions of 1%, 0.1%, 0.01% and 0.001% were prepared by adding an appropriate volume into a known weight of aqueous ethanol. Using a Rainin L300 pipette, 20-300µL of the relevant stock solution was added to clean glassware and brought up to 50g of base solution (dilute ethanol or beer) for sensory evaluation. Glassware was presented randomized, blind coded and lidded.

Model System Preparation: Ethanol solutions of 5%, 10% 15% ABV were prepared using 95% food grade ethanol and dionized water from the Milli-Q reagent water system.

Beer Production: Two unhopped beer bases, a lager and brown ale, were brewed in the Oregon State University pilot brewery.

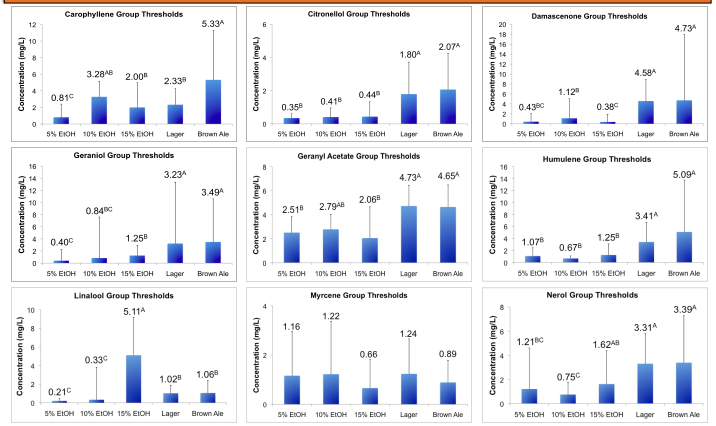
Lager
(66% Pale 2 row, 32.5% Clearsweet-95, 1.5% Acidulated Malt)
•Fermented with Bohemian Lager™ yeast (Wyeast2124) for 14 days at 58°C.
•Filtered and kegged with 0.5-1 vols. CO_2.
•Left uncarbonated for sensory evaluation.
ABV: 4.6% Final Apparent Gravity: 0.67°P

Brown Ale
(86% Pale 2 row, 5% Munich, 5% Chocolate, 4% Simpson-155)
•Fermented with American Ale™ yeast (Wyeast 1056) for 11 days at 68°C.
•Filtered and kegged with 0.5-1 vols. CO_2.
•Left uncarbonated for sensory evaluation.
ABV: 6.4% Final Apparent Gravity: 4.08°P

Sensory Evaluation: Group sensory thresholds were determined using the ascending method of limits test methodology by 3-alternative forced choice, (ASTM E679). Forty-five thresholds were determined by presenting 22+ assessors with seven triangles (1 compound added, 2 blank base) in which the concentration doubled at each step. Panelists, trained to the testing methodology and provided compound and blank references, evaluated three thresholds tested at a time in nineteen sessions including four retests. Retesting consisted of additional concentrations for assessors that missed the last set or correctly identified the compound in the first set.

Statistical Analysis: Threshold values were computed in MS Excel. Group thresholds were determined by taking the logarithmic mean of individual values, the geometric mean between the last incorrect and first consecutive correct response. The deviation of the threshold was calculated using the standard deviation for a lognormal distribution. To compare across bases, analysis of variance (ANOVA) was performed on log transformed individual values, approximately normally distributed, using Minitab16 statistical software.

Results



Figures 1-9. Group Thresholds (mg/L) and Standard Deviations for Hop Compounds in Different Water-Ethanol and Beer Bases

Table 1. Mean, Median and Counts for Group Thresholds for Hop Compounds in Different Bases

Compound		Base					
		5% EtOH	10% EtOH	15% EtOH	Lager	Brown Ale	P-value
Carophyllene	Log Mean	0.81^{C}	3.28^{AB}	2.00^{B}	2.33^{B}	5.33^{A}	<0.001
	Median	0.62	4.95	2.44	1.67	3.38	
	Count	29	32	31	25	26	
Citronellol	Log Mean	0.35^{B}	0.41^{B}	0.44^{B}	1.80^{A}	2.07^{A}	<0.001
	Median	0.29	0.29	0.58	2.37	2.40	
	Count	32	22	25	25	28	
Damascenone	Log Mean	0.43^{BC}	1.12^{B}	0.38^{C}	4.58^{A}	4.73^{A}	<0.001
	Median	0.32	0.64	0.32	5.19	5.26	
	Count	30	26	29	28	26	
Geraniol	Log Mean	0.40^{C}	0.84^{BC}	1.25^{B}	3.23^{A}	3.49^{A}	<0.001
	Median	0.46	0.60	1.19	2.44	4.94	
	Count	30	33	28	27	28	
Geranyl Acetate	Log Mean	2.53^{B}	2.79^{AB}	2.06^{B}	4.73^{A}	4.65^{A}	<0.001
	Median	4.02	3.99	1.97	6.32	6.40	
	Count	31	25	34	24	26	
Humulene	Log Mean	1.07^{B}	0.67^{B}	1.25^{B}	3.41^{A}	5.09^{A}	<0.001
	Median	1.24	0.62	1.22	3.33	3.38	
	Count	28	26	31	29	28	
Linalool	Log Mean	0.21^{C}	0.33^{C}	5.11^{A}	1.02^{B}	1.06^{B}	<0.001
	Median	0.15	0.30	7.47	0.80	0.81	
	Count	24	29	31	26	26	
Myrcene^{NS}	Log Mean	1.16	1.22	0.66	1.24	0.89	0.156
	Median	1.10	1.09	0.54	1.10	1.39	
	Count	24	24	24	24	27	
Nerol	Log Mean	1.21^{BC}	0.75^{C}	1.62^{AB}	3.31^{A}	3.39^{A}	<0.001
	Median	1.21	0.60	2.37	4.86	4.92	
	Count	32	28	29	27	26	

^{NS} attributes are not significant ($p > 0.05$).
Sample means with different superscripts within a row are significantly different from one another at $p < 0.05$ by Tukey's HSD test.

Conclusions

The aroma thresholds for nine important aromatic hop compounds were established, using the ASTM E679 methodology, for five different water-ethanol and beer bases. This study shows strong evidence that thresholds vary dependent on base studied. In model systems, six of the nine compounds were significantly effected by ethanol content of the base. In beer, thresholds in the brown ale where not significantly different from lager, except for carophyllene. Further work to correlate chemical properties of the compounds to the results is planned.

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