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## Background

### Introduction

The recent explosion of innovation sweeping through the craft beer market has been highlighted by brewer's ability to maximize extraction of flavor and aroma characteristics from hops. These innovations, however, may come with a trade off: larger dry hop additions and innovative dry hopping techniques can shorten the shelf-life of the resulting beer. A modern craft IPA shelf-life may range from 2 months to 3 months, after which point the advantage of brewing a hoppy beer becomes an equally large liability with a product that is oxidized, no longer retaining the defining flavor/aromas. The ability to increase the shelf-life of a hoppy beer through an enhancing ingredient to six months carries implications to: distribution, operational efficiency, consistency, COGS, and most importantly quality.

In this study we present a new approach to preserving the flavor and aroma character of hoppy beers through the addition of a customized hop extract and unique flavor. We provide sensory data in after six-seven months demonstrating the beer still retains the cornerstones of its character, and further does not contain the oxidation, cardboard or other common off flavors associated with aging hoppy ales.

### Flavor Development

- Hop/flavor ingredient was formulated to achieve two key objectives: (1) to stabilize and preserve the flavor/aroma of the beer for a period of six months, (2) to maintain a balance between flavor and aroma over six months.
- Initial crude hop oil was obtained through distillation and reformulated to achieve a preparation to increase the background hoppy flavor/aroma and increase the beer shelf life.
- In addition to reformulated hop extract a secondary flavor was introduced to both demonstrate flavor stability and to evaluate the affect of an introduced flavor on beer stability over time.
- Several flavors were trialed (peach, passionfruit, pineapple, mango). Peach was selected for presentation from this study, but the other flavors showed similar flavor stability.

### Dosing Strategy and Methodology

- To minimize interferences commonly associated with traditional "carriers" or emulsifying agents grain neutral spirt (GNS) was chosen as the medium with which to dilute the flavor/hop oil ingredient.
- The ingredient (defined as 1% of the hop oil reformulation + peach flavor in GNS) was mixed in the finished beer at both 0.5% and 1.0% by weight.

## Analysis and Methods

### Brewing Curation

Beers were produced at the Haas Nanobrewery using a 20-gallon split mash into three 5-gallon brews. The beers were early kettle hopped with bittering extract (FLEX) to 30 IBUs followed by a whirlpool addition of 2 lb./bbl (Mosaic T-90 pellets). The three beers were dry hopped at 2 lb./bbl (Mosaic T-90 pellets). The flavored dry hop products were dispersed into ethanol (Everclear) and dosed into transfer kegs just prior to cold crash.

### Sensory Evaluation

Sensory Evaluation: Sensory Analysis was performed by the John I Haas trained sensory panel (n=11). The panel was trained in descriptive analysis using the BarthHaas Unified Sensory ("Hopsessed") Lexicon and the Haas Aroma Standards. Evaluations were performed in duplicate on an 11-point scale for the 12 attributes of the Hopsessed Lexicon in addition to hedonic liking and overall aromatic impact (OHA). Means and significant differences were determined by Analysis of Variance (ANOVA) with Tukey's HSD post hoc analysis. Statistical analysis was performed using XLSTAT v. 2020.3.1.

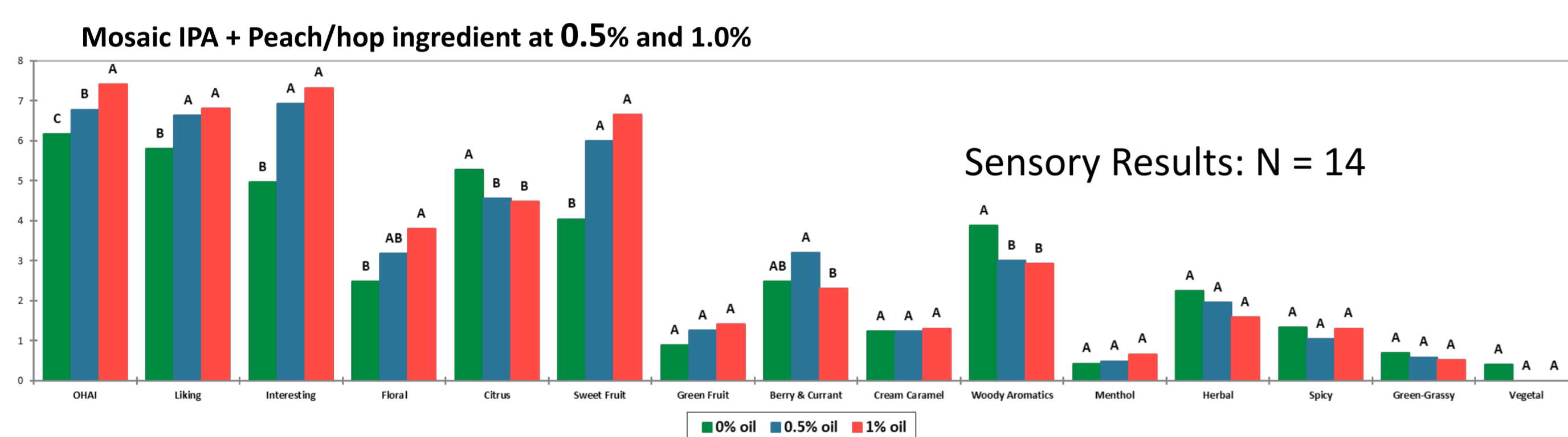
### Analytic Confirmation

**Sampling:** Beers were sampled for chemical analysis at 4 time points in 50 mL brown glass vials and immediately frozen for 24 hours prior to analysis. The sampling time points were the following; 1) "Fresh" beer, two weeks after cold crash. 2) At one month age. 3) At three-month age. 4) At 7 months age.

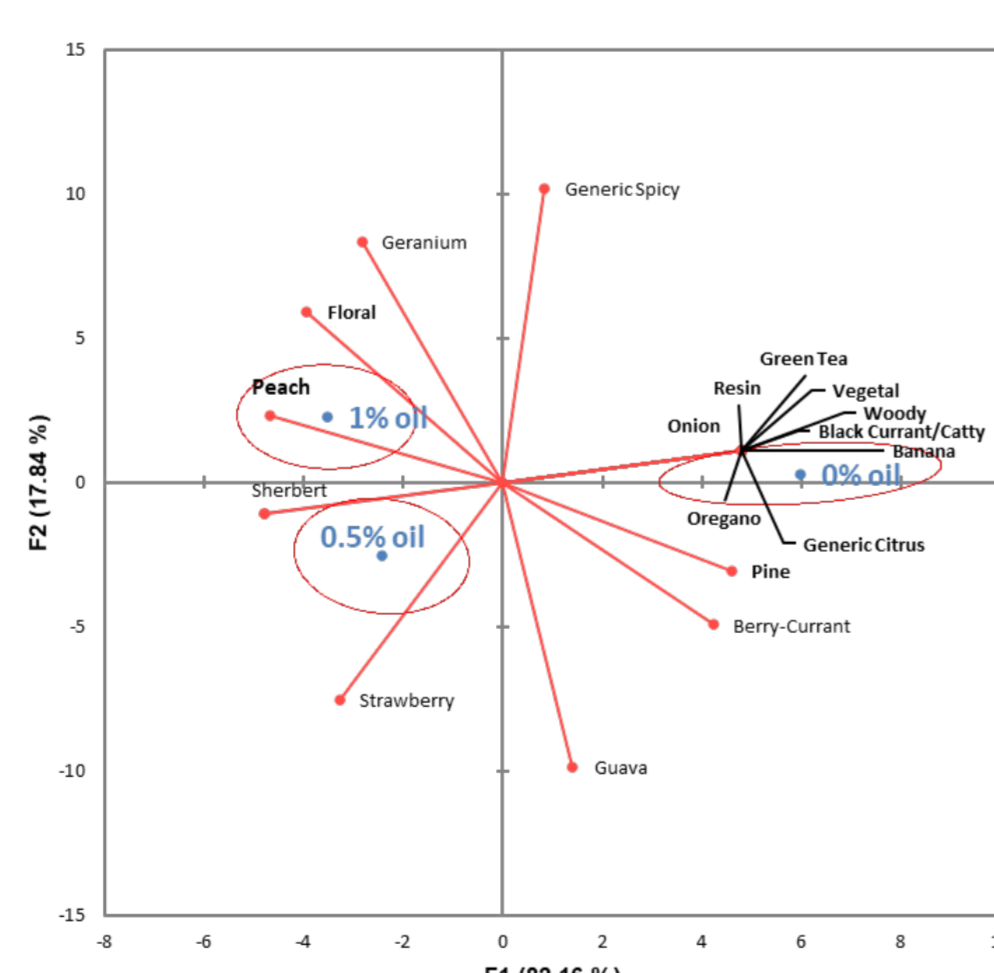
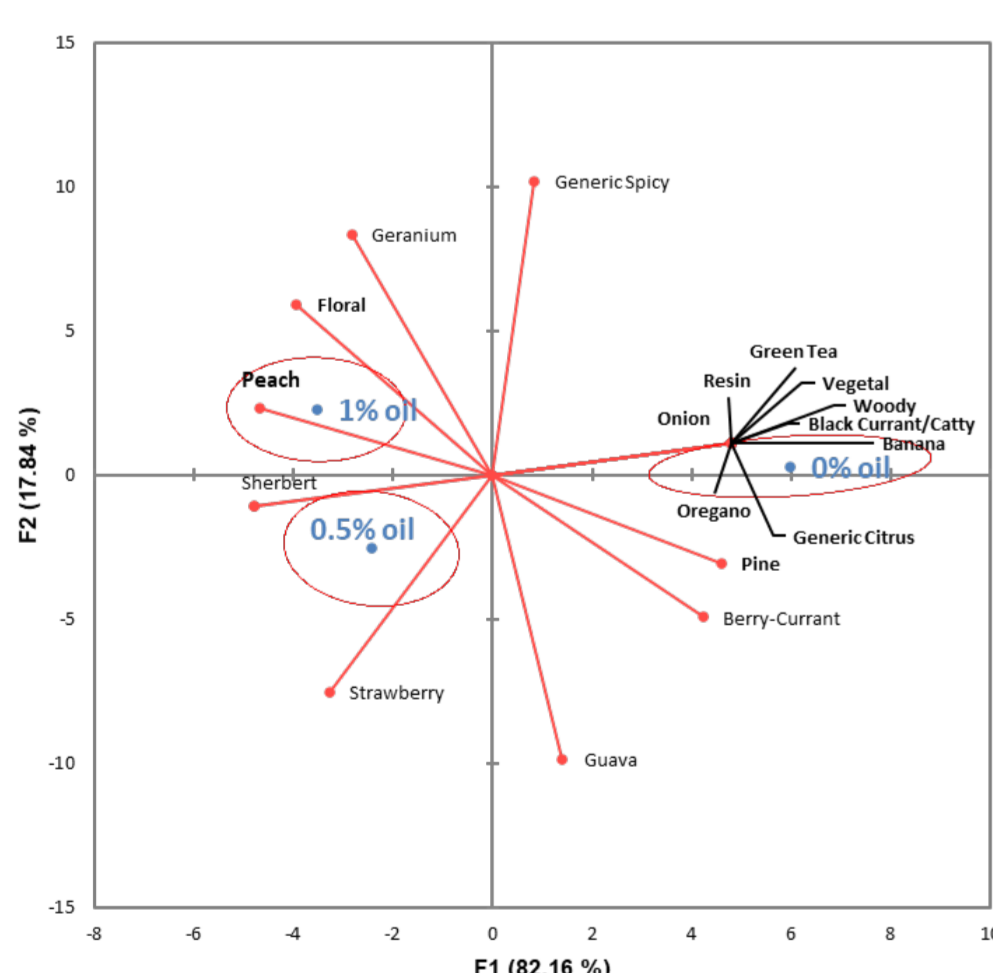
**Chemical Analysis:** 20 mL samples of beer were extracted via stir bar sorptive extraction (Twister) for 2 hours at 1000 rpms. Extracted compounds were analyzed using a Gerstel modified Agilent GC-MS (Agilent 7890B – single quadrupole). Samples were injected using the Gerstel thermal desorption unit (TDU 2) / cryogenic injection system (CIS 4). GC column; Agilent DB-5 LTM. Ramp conditions; 40 C for 2 minutes – 6 C/min to 125 C (no hold) – 8 C/min to 230 C and hold for 5 minutes. Compounds were identified using the Agilent Mass Hunter program with the NIST 14 library. A list of the identified compounds by chemical class is provided in an attached PowerPoint. Relative amounts of the compounds were determined using the Agile integration method within the Mass Hunter program.

## Results

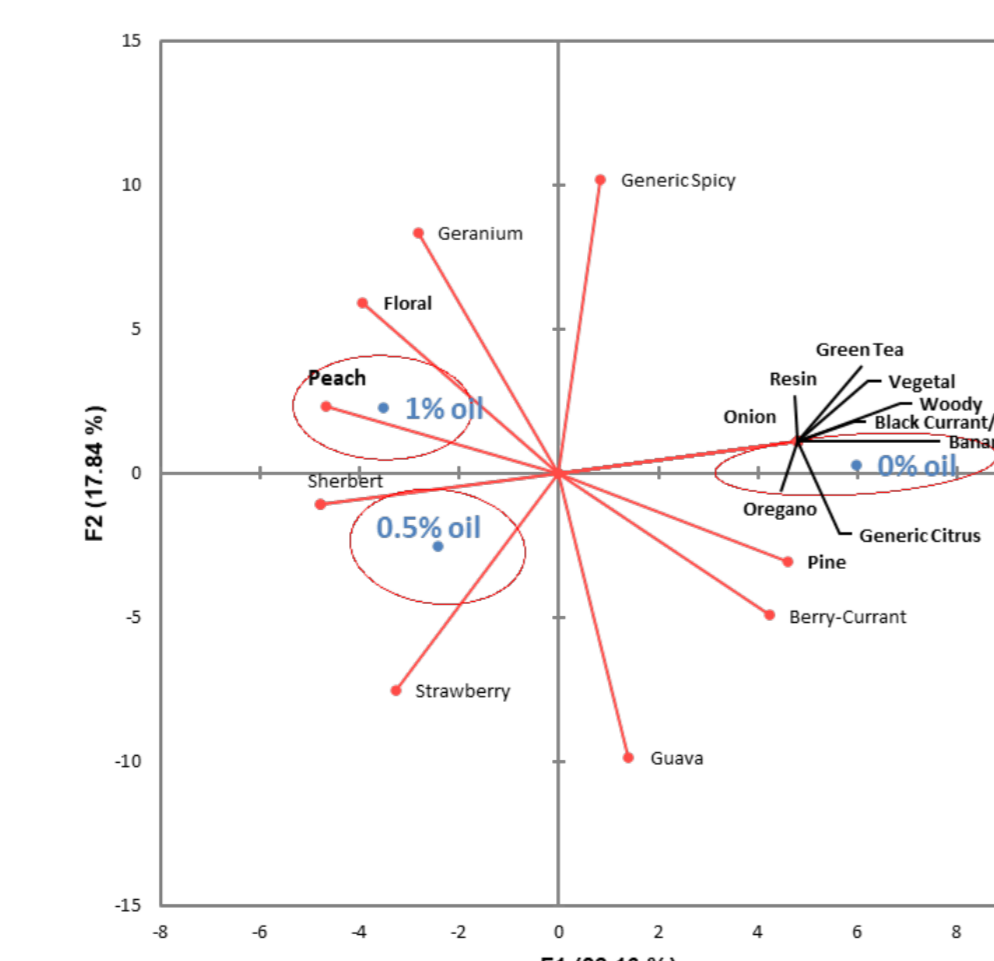
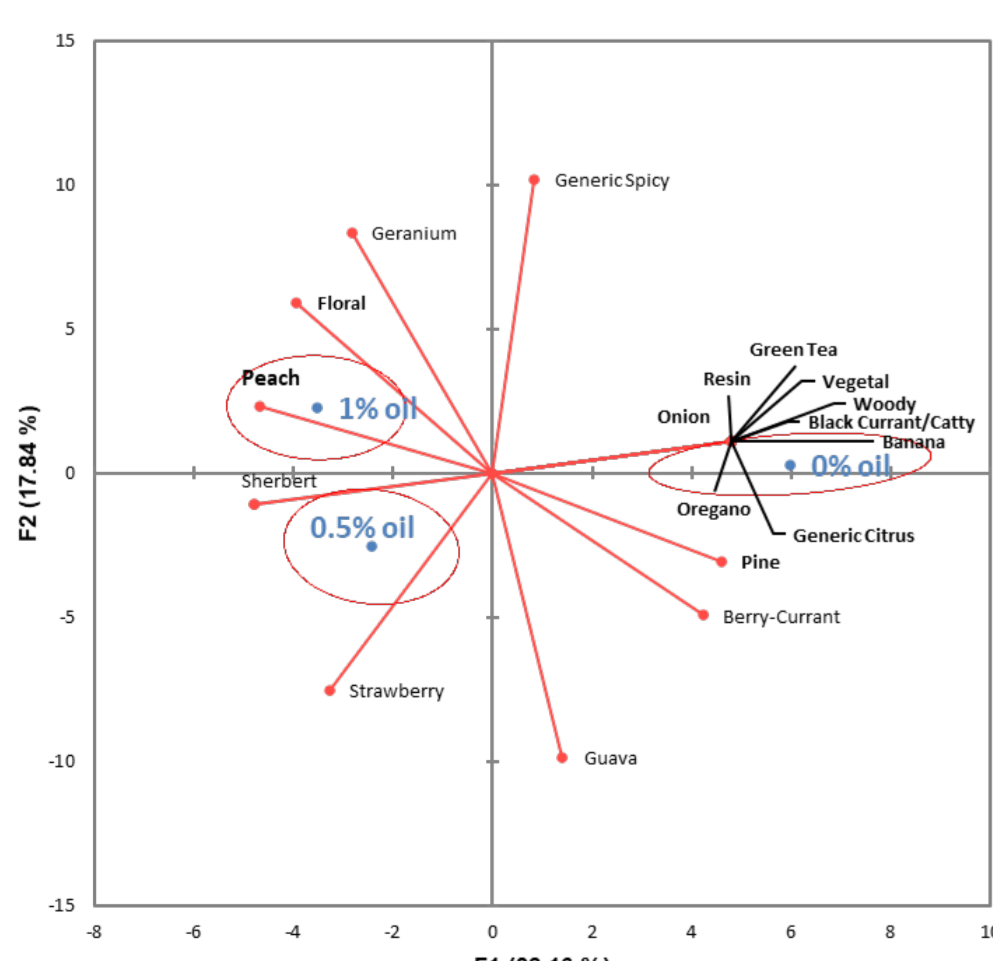
### Sensory



- The addition of the terpenes at 0.5% has a significant impact on OHA, Liking, Interesting, Citrus (decrease), Sweet Fruit, Woody, and a swing in Berry.
- Increasing to 1% only impacts the OHA and Floral.

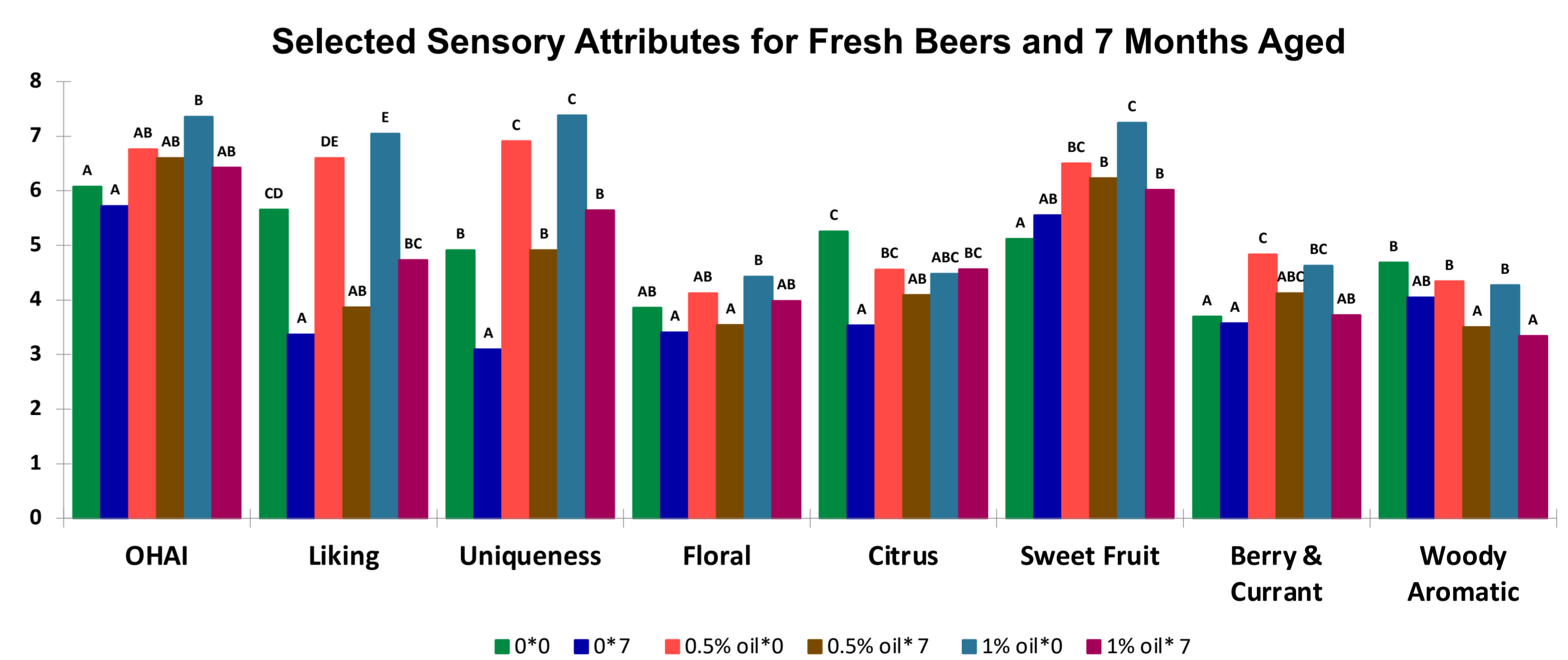


- 0% oil (Control) displays typical true-to-type Mosaic character (Citrus, Catty, Sweet Fruit, Woody/Resin, Herbal, OG).
- The addition of the Peach/Oil blend causes a significant increase in Floral, most-closely related to Geranium-type aromas.



- The addition of the Peach/Oil blend causes a significant increase in Sweet Fruit, most-closely related to the target Peach aroma.
- The addition of the blend also causes a swing and significant decrease in Berry-type aromas – The initial addition causes a swing and amplification of Berry character, moving it away from a generic, "Catty"-type berry aroma to a sweeter, Strawberry aroma. The final, significant drop in berry character appears to be related to the increase in strong, specific Peach aromas.

### Shelf-Life



## Conclusions

- The presence of hop oil/peach ingredient results in higher flavor/aroma stability through a 7-month shelf-life study.
- Flavor has significant impact of beer sensory, suggesting added flavors ability to selectively enhance (and target) specific characteristics and profiles is very strong.
- Using such an ingredient in a modern brewing application may have dramatic impacts on product shelf-life. Increased shelf-life could be leveraged to positively impact: operations, distribution, consistency, COGS and quality of final product.
- Additional flavors could expand brewers ability to generate complimentary IPA flavor profiles beyond what is currently available/cost effective for their current brewing process.

## Next steps

- Repeat experiments across more hop profiles, and more flavor profiles.
- Separate contribution of hop oil reformulation and flavor formulation to the final stability and character of the beer.
- Correlate analytic data with sensory data to be better understand mechanism(s) for increased stability and shelf-life of resulting beer.
- There may be a need to develop an additional carrier agent beyond GNS.

## Acknowledgments

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