

Hop Oil Tracking and Optimization through Benchtop Fermentations

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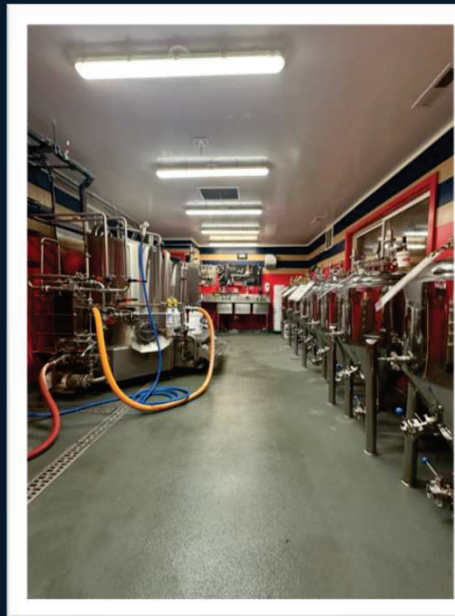
Today's Roadmap

- Why a benchtop brewing model?
- How do we conduct and apply this benchtop model?
- Overview of HyperBoost
- Recent trial data understanding the role of hop oil components in beer
 - *Investigation into the independent effects of T-90 and HyperBoost and their combination*
 - *Understanding how hop oil components change with varying T-90 and HyperBoost dosings*

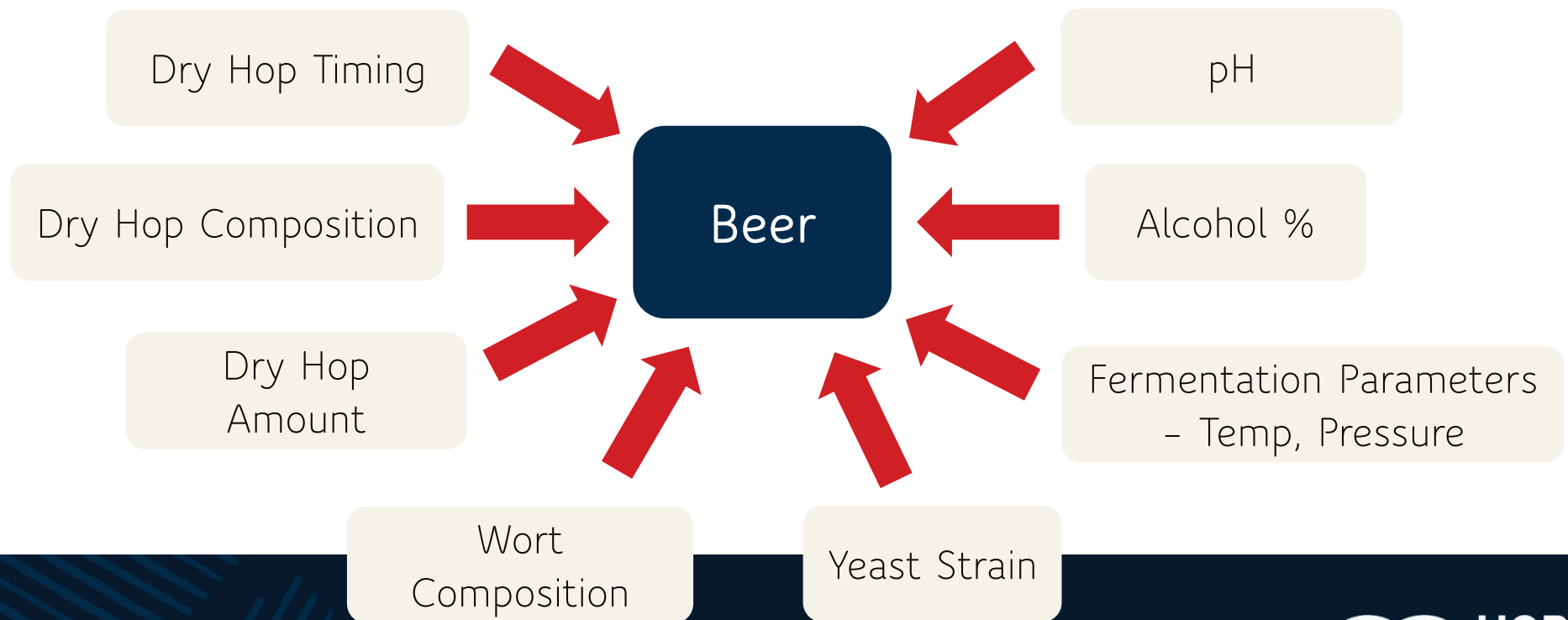


Current YCH Pilot Brewery Setup

- 5hL brew system
- Capability for split whirlpool and cool pool applications
- Eight – 1hL cylindroconical fermenters
- Plate & frame filtration capabilities



Brewing is a Multivariable Process



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Scaling Down



100 L



0.5 L

Benefits of Each Methodology

Pilot Brewhouse

Practical, real-world impact of experiments – reflective of how it may behave in a brewery

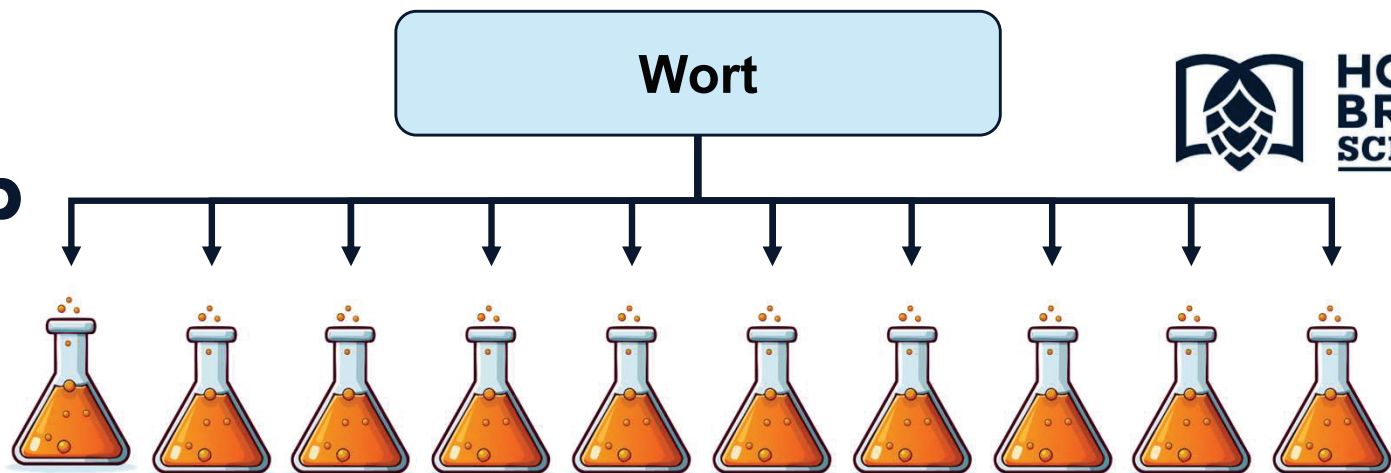
Benchtop Flasks

Controlled, replicable comparisons at small scale – built to isolate variables and generate hypotheses, not confirm final beer character

Why A Benchtop Brewing Model?

Factor	Benchtop Flask Method	Pilot Brewhouse
Hop Sample Amount	Small (< 10 g)	Large (> 500 g)
Throughput	Up to 10+ flasks can be run simultaneously	Maximum 5 trials can be run from single wort
Speed & Turnaround Time	1-2 weeks	2+ weeks
Replication	Allows for experimental replicates	Can be, but impractical
Cost of Experiment	Low	High
Sensory Evaluation	Aroma only	Full sensory evaluation
Carbonation	Flat – Semi-Carbonated	Fully carbonated

Process for Benchtop Brewing

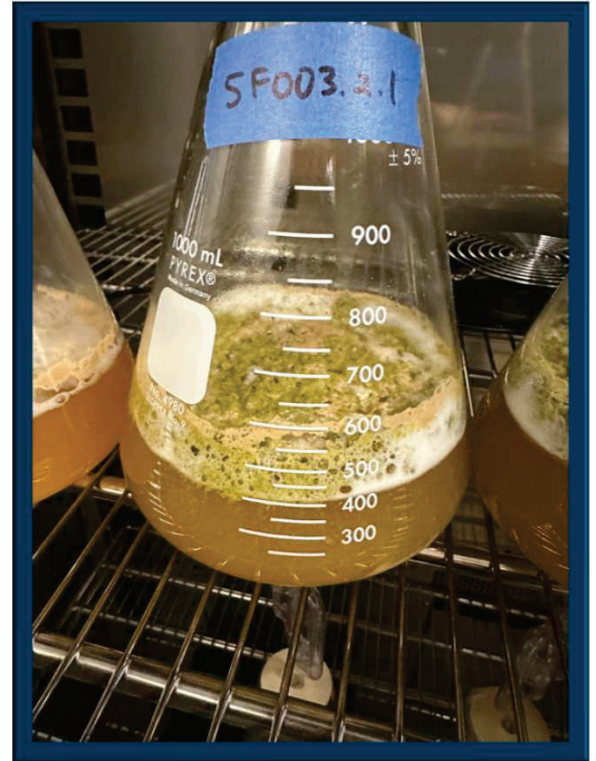


Fermentation & Dry Hop Additions

*Whole leaf, T-90, Cryo, and oil products can be evaluated
Dry hop timing can be at pitch, mid-fermentation, or post-fermentation*

Sensory Evaluation & Analytical Measurements

*Gravity, alcohol, hop acids, hop/beer aroma compounds analyzed
Aroma only sensory evaluation by YCH panelists*



Recent Trials in Tracking Hop Oil Components

How T-90 and HyperBoost shape hop oil composition, alone, together, and across dose?



HyperBoost Overview

- >40% total oil content
- Non-emulsified liquid format
- 1g HyperBoost $\approx$ 100g T-90
- Replace 25-50% of dry hop



PRODUCT TYPE	PRODUCT DESCRIPTION	BITTERING / EARLY KETTLE	LATE KETTLE	WHIRLPOOL	DIP HOP / DAY 0 ADDITION	ACTIVE-FERM DRY HOP (DAY 2-3)	POST-FERM DRY HOP	BRITE TANK / POST-CRASH
HYPERBOOST™	Oil-Boosted Hop Extract	×	×	⊖	++**	++**	+**	--

⊕ Most Efficient Use of Product ⊕ Good Choice ⊖ More Efficient Choices Available

-- May Provide Strong Terpene Aromas × Do Not Use In This Application

** Dosing Rate Varies, Start at 25-50% of Dry Hop

Citrus, Tropical

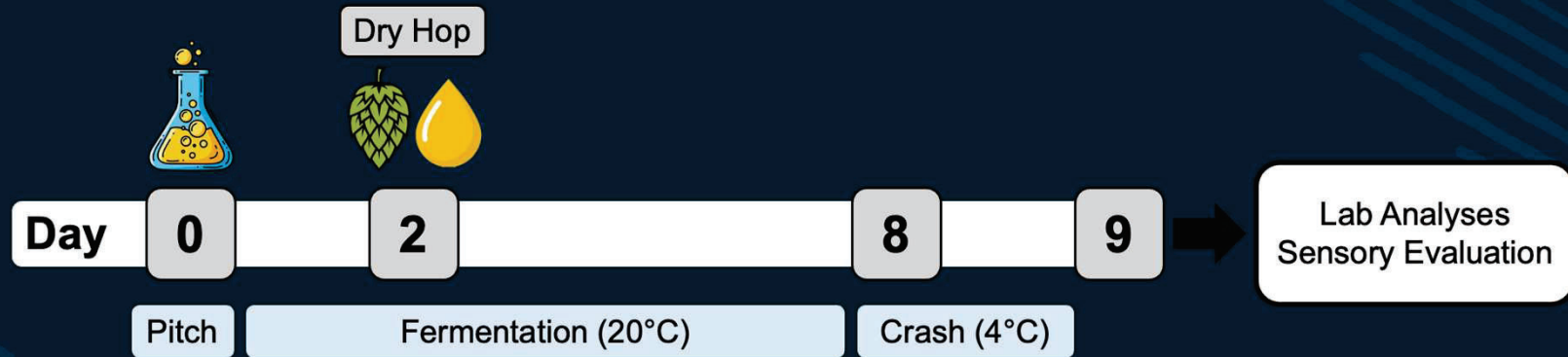
Pine, Resinous

Experiment 1

Investigation into the independent effects of T-90 and HyperBoost and their combination



Brewing Process for Experiments 1 & 2



Both experiments used Citra T-90 and Citra HyperBoost

Study Design

Investigation into the independent effects of T-90 and HyperBoost and their combination

T-90 Only
Total DH:
7.5 g/L

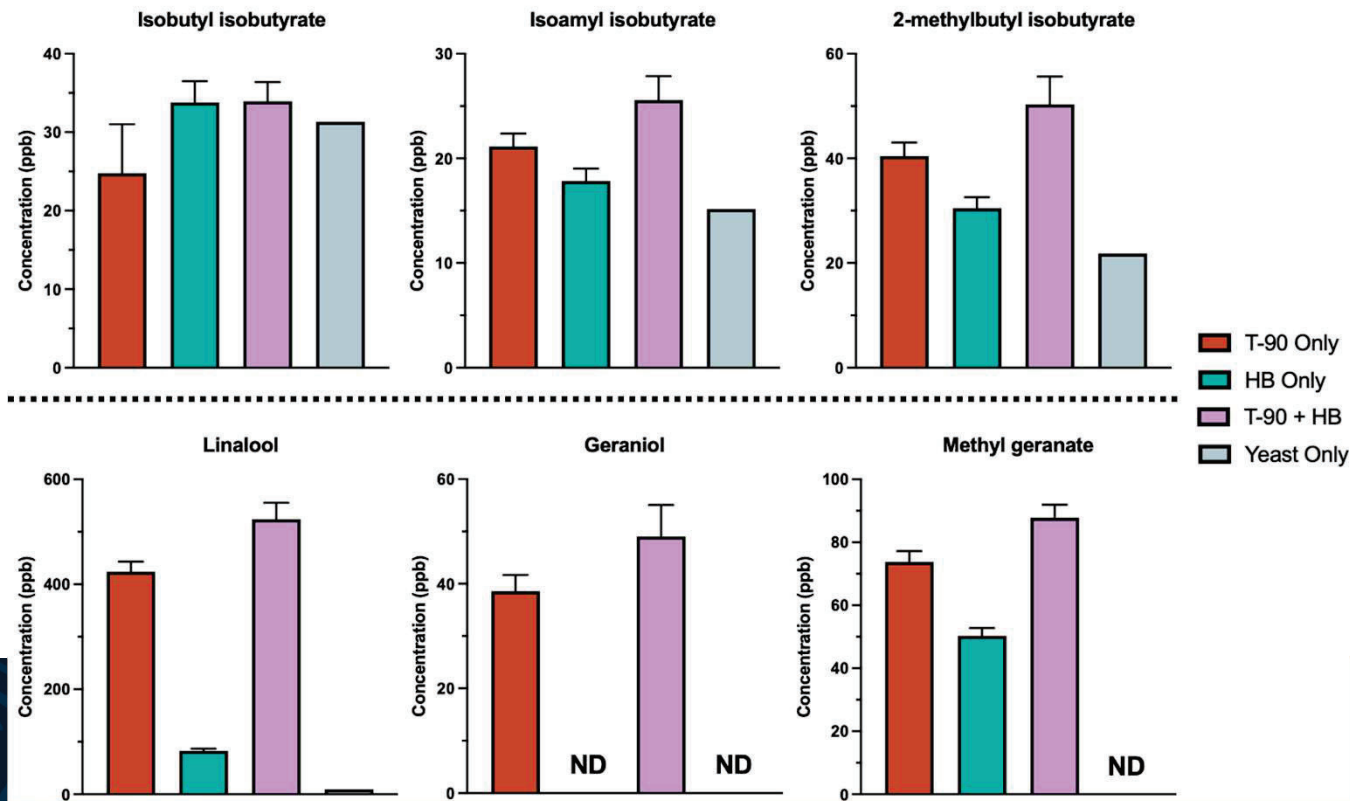
HyperBoost Only
Total DH:
*2.5 g/L**

**HyperBoost
dosing is shown
as T-90
equivalent*

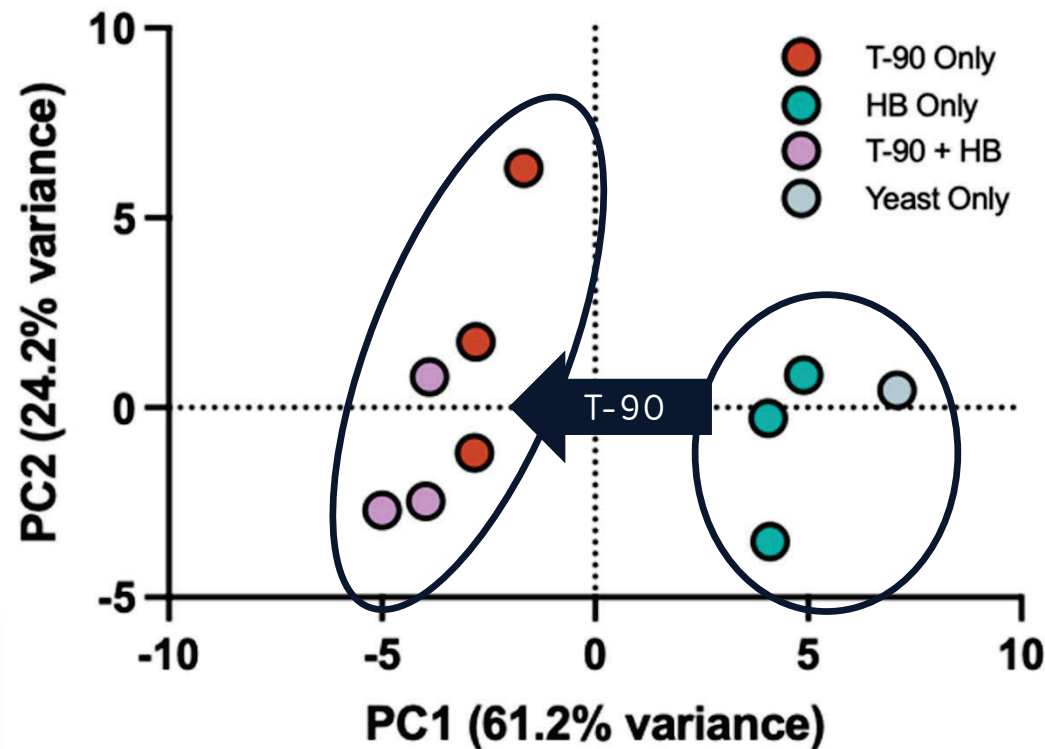
T-90 + HyperBoost
Total DH:
10 g/L

Unhopped Control
Total DH:
0 g/L

T-90 + HyperBoost Increases Most Compound Levels Beyond Either Treatment Alone

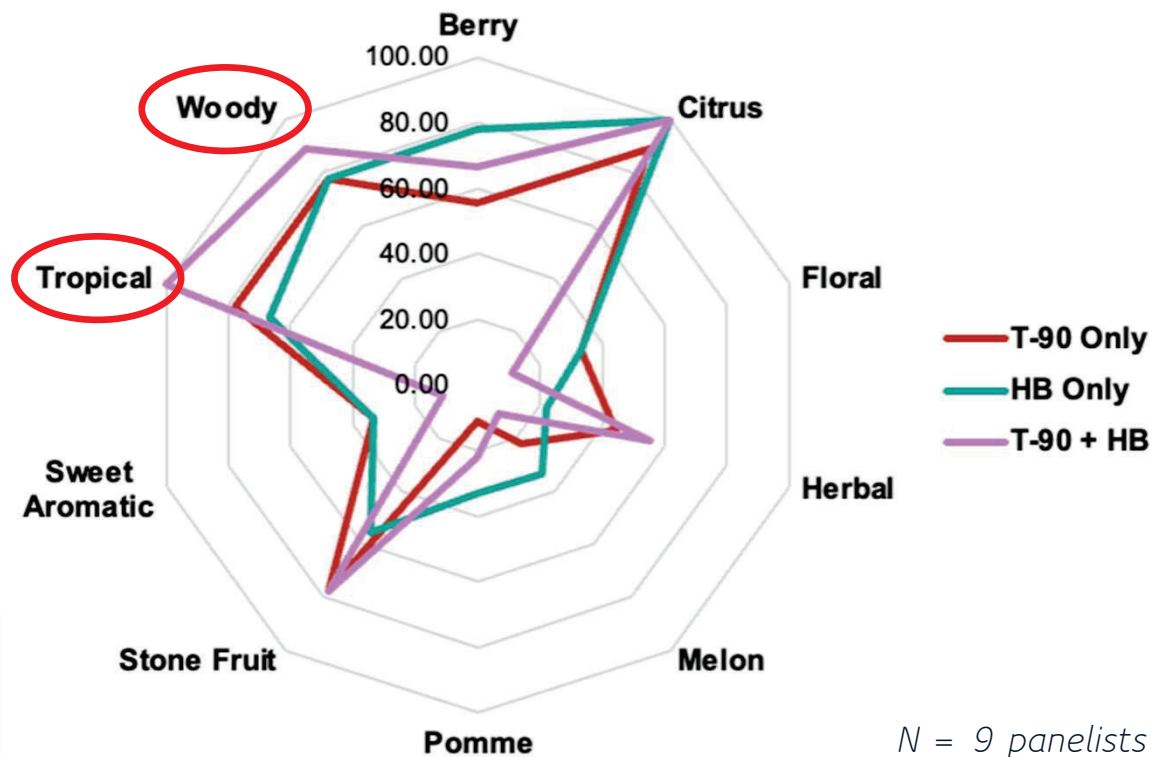


T-90 Presence – Not HB – Drives Separation in the Full GC-MS Compound Profile

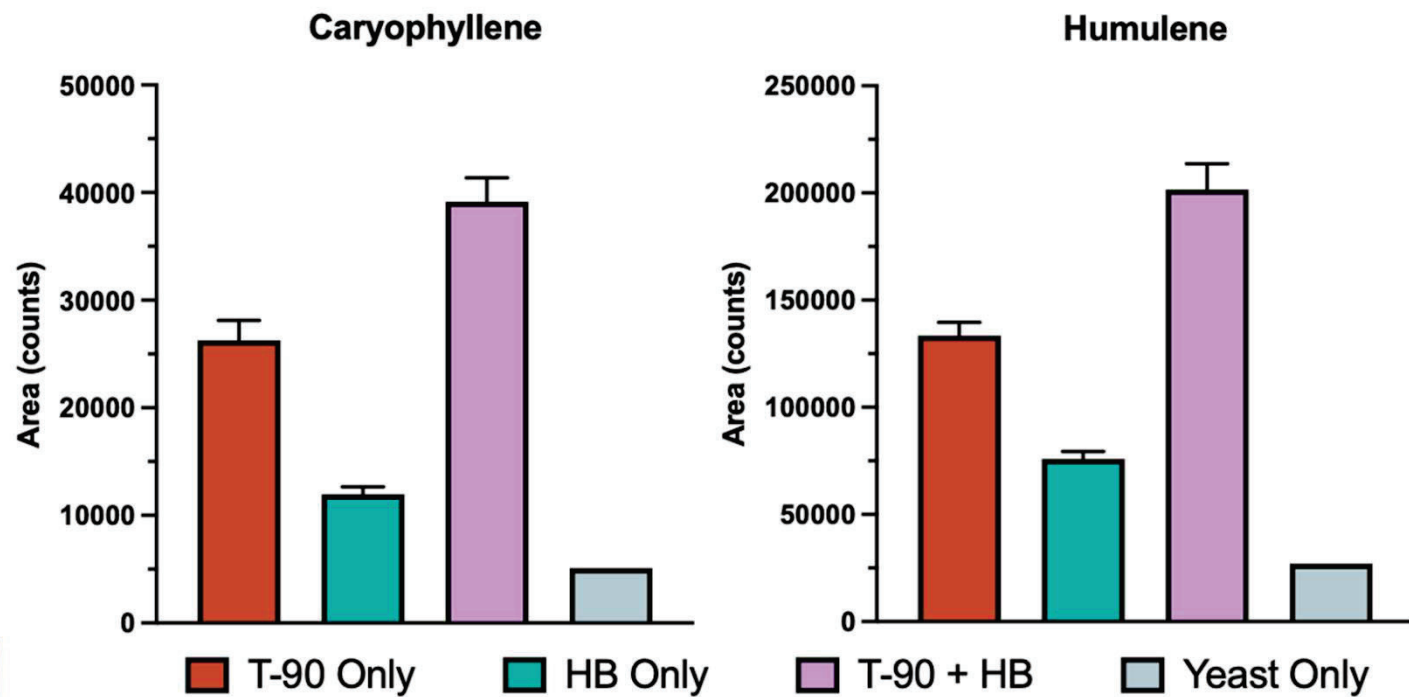


Each point represents one fermentation sample, positioned according to its full GC-MS aroma profile across 35 individual compounds, reduced to two dimensions (PC1, PC2) via principal component analysis.

T-90 + HyperBoost Amplifies Tropical and Woody Aroma Beyond Either Alone



T-90 + HyperBoost Combine Synergistically to Boost Caryophyllene and Humulene



Experiment 1 Takeaways

- HB alone, at recommended replacement dosing, doesn't meaningfully shift the aroma profile.
- T-90 presence drives the aroma profile separation – *suggesting that pellet material is a dominant factor shaping overall aroma chemistry.*
- $T-90 \neq T90 + HB$ – *sensory evaluation highlights increased tropical, woody (piney), while still retaining T-90 characteristics (citrus, stone fruit)*

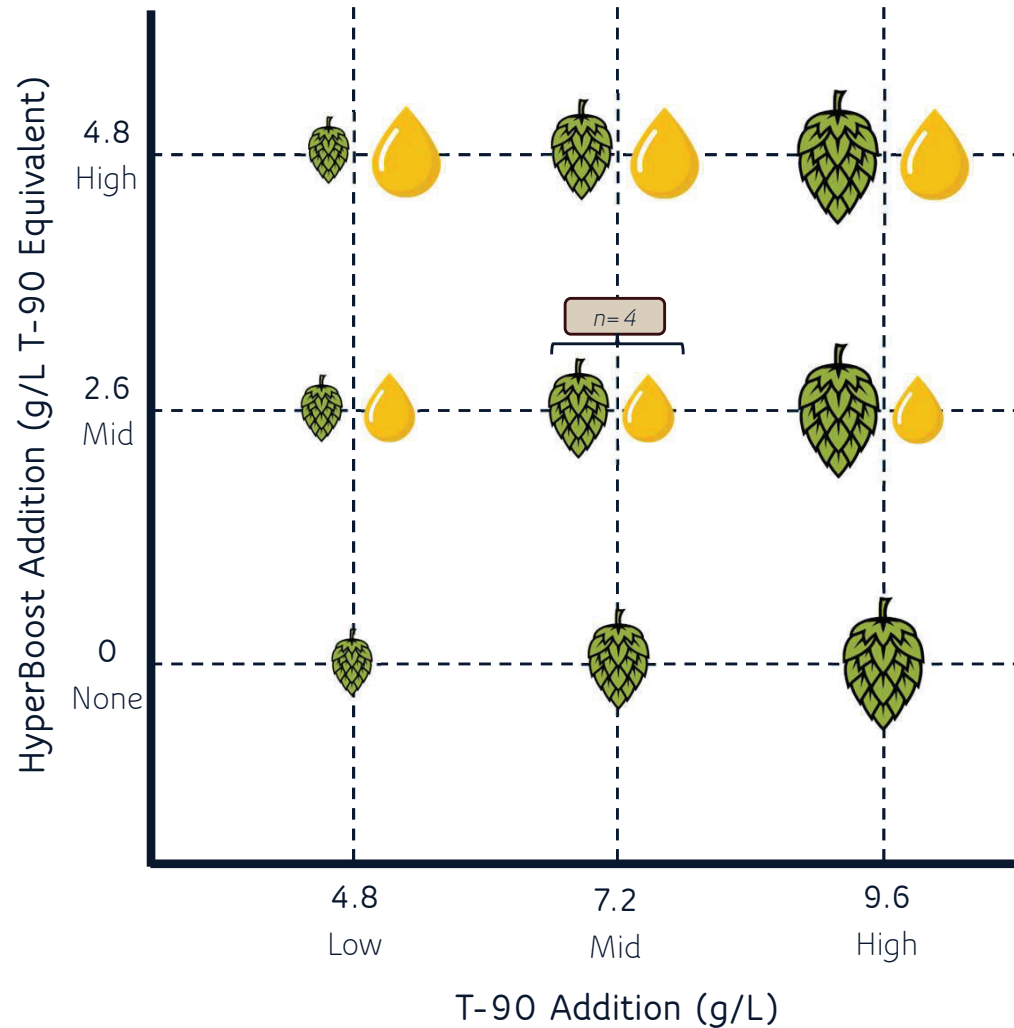
Experiment 2

Understanding how hop oil components change with varying T-90 and HyperBoost dosings



Study Design

We ran a 12-flask experiment testing different amounts of T-90 and HyperBoost – separately and combined – to see how the mix and dose of each one shapes the beer's hop aroma.

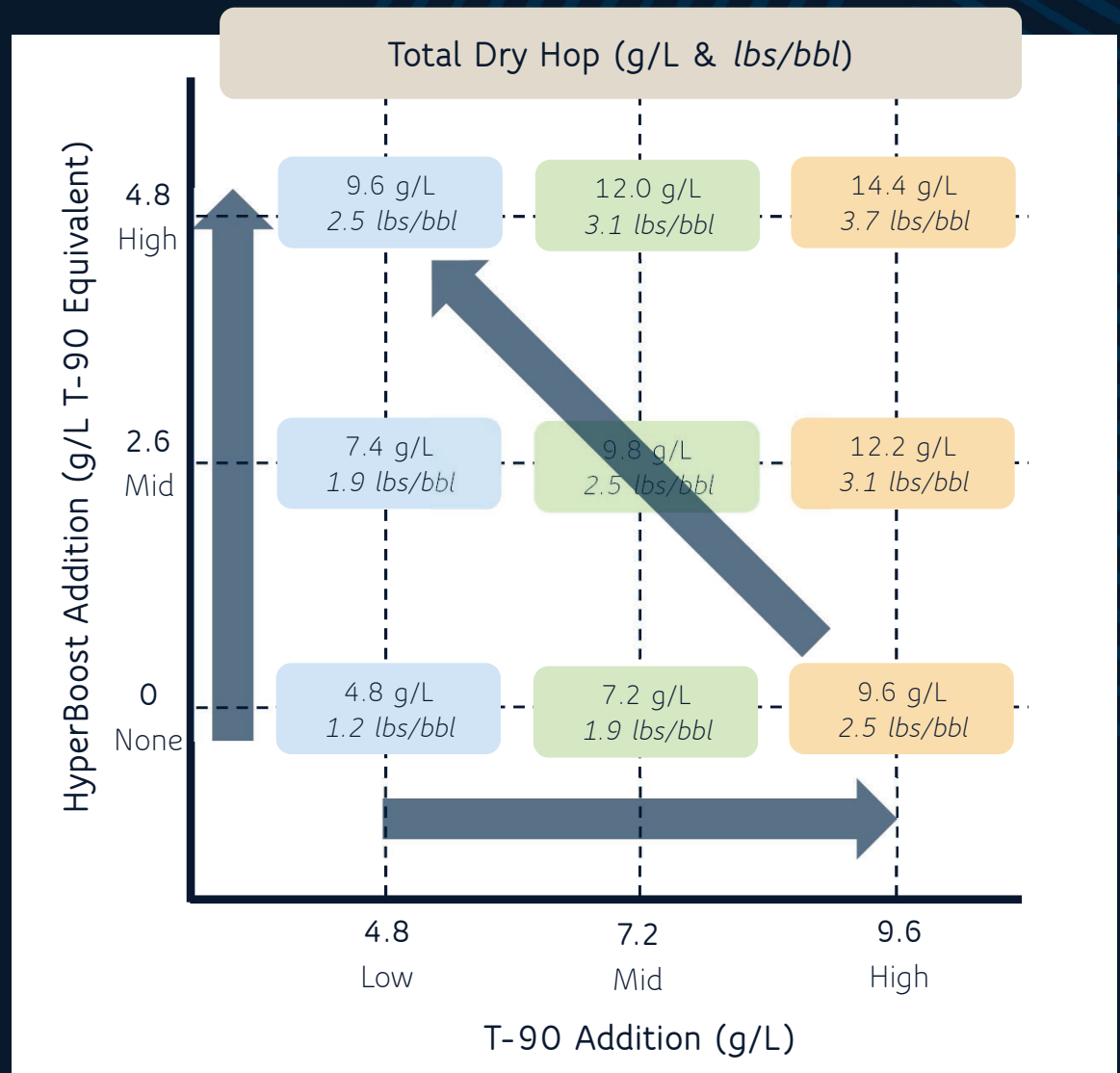


Study Design – Total Dry Hop Equivalent

Across each row – isolates the effect of T-90 dose, holding HB constant

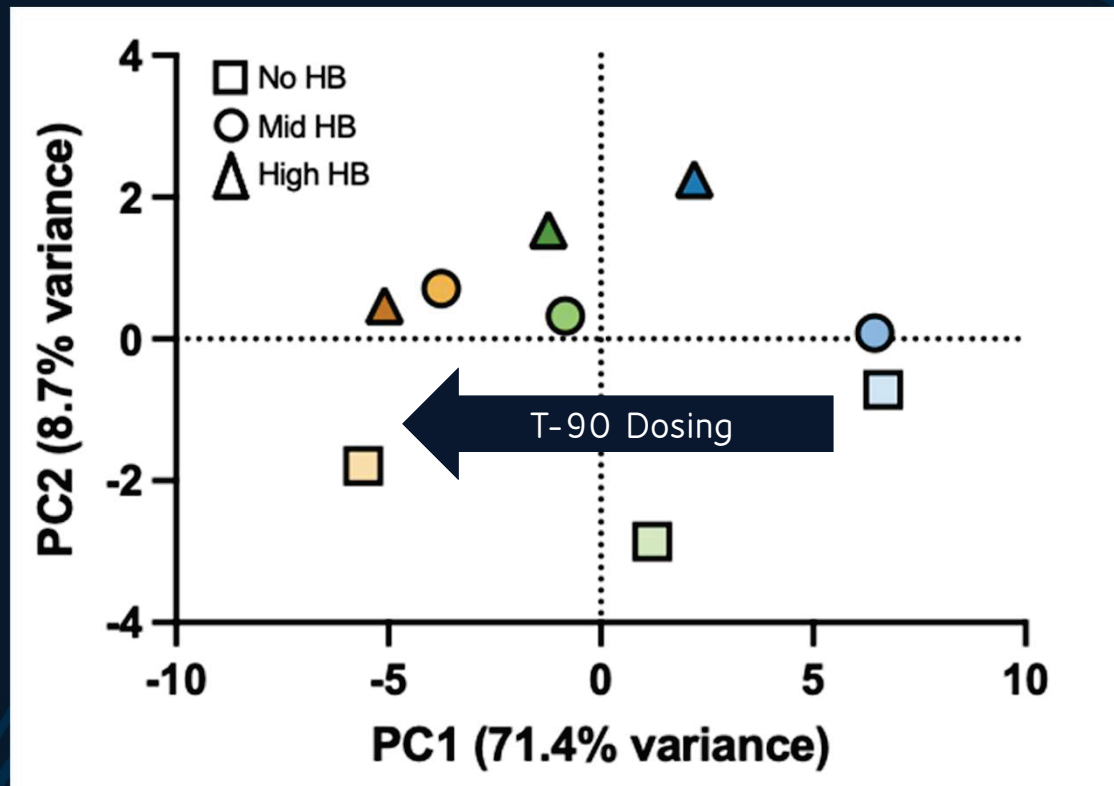
Up each column – isolates the effect of HyperBoost dose, holding T-90 constant

Along the center diagonal – compares combinations at the same total dry hop rate, revealing how T-90 and HB interact when substituted for one another



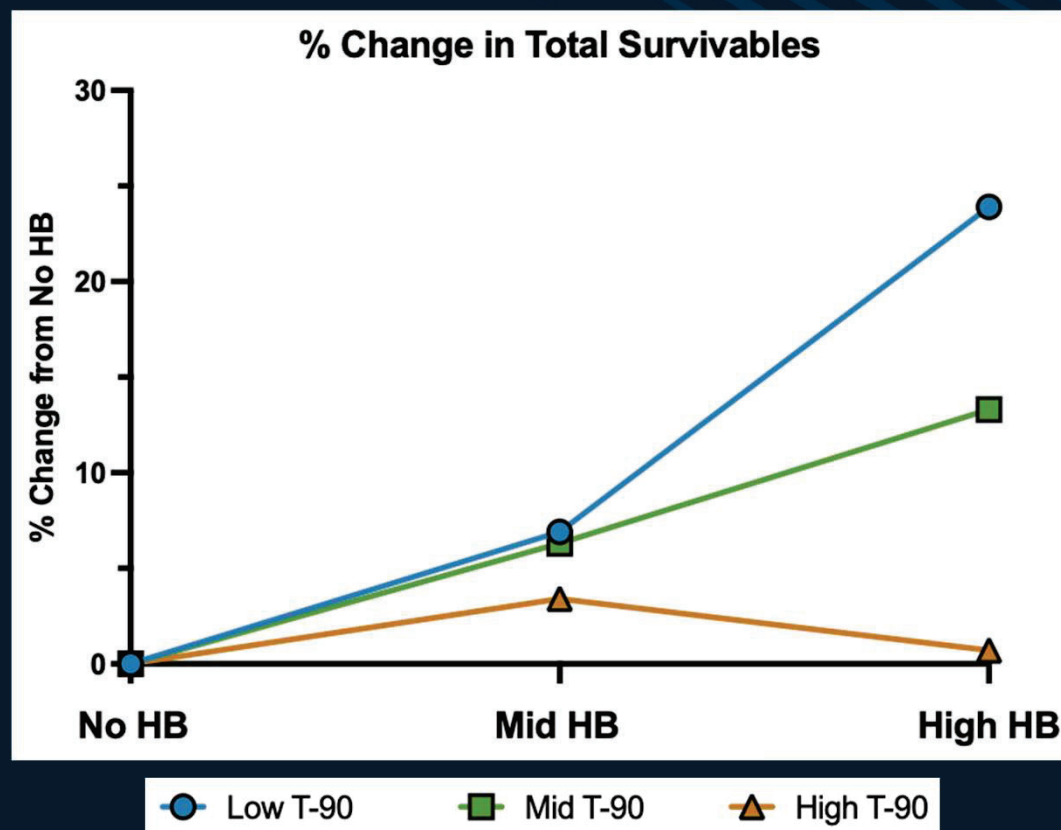
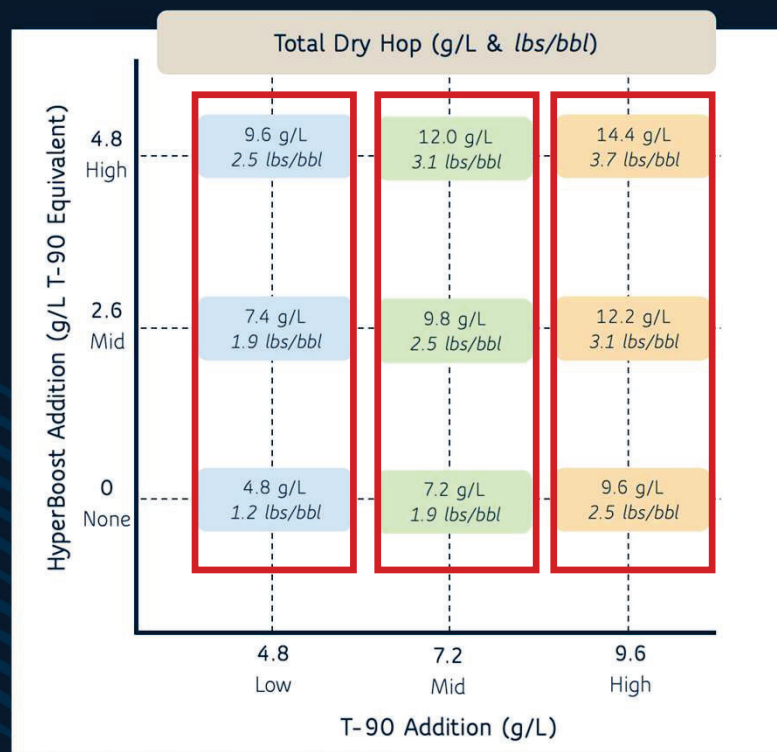
Increasing T-90 Drives Aroma Profile Separation – HB Shifts It Only Slightly

Blue = Low T-90
Green = Mid T-90
Orange = High T-90

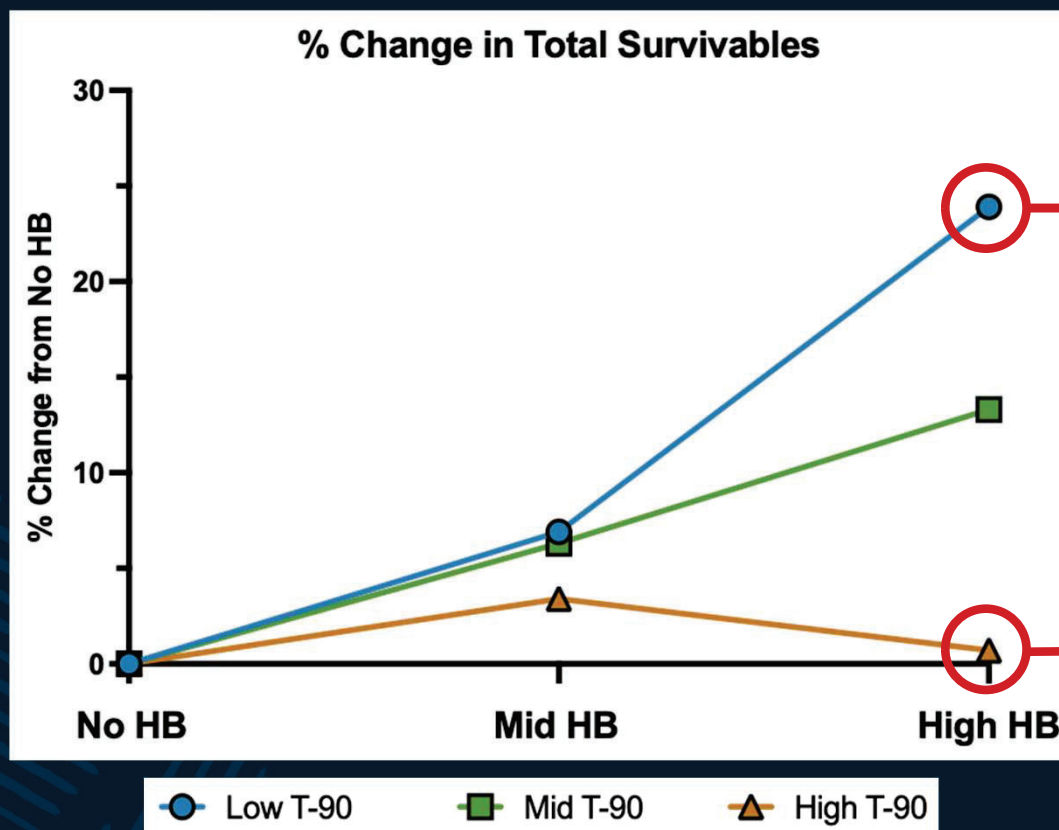


Each point represents one fermentation sample, positioned according to its full GC-MS aroma profile across 35 individual compounds, reduced to two dimensions (PC1, PC2) via principal component analysis.

Addition of HyperBoost at a Lower T-90 Dose Increases Total Survivables Compared to a Higher T-90 Dose



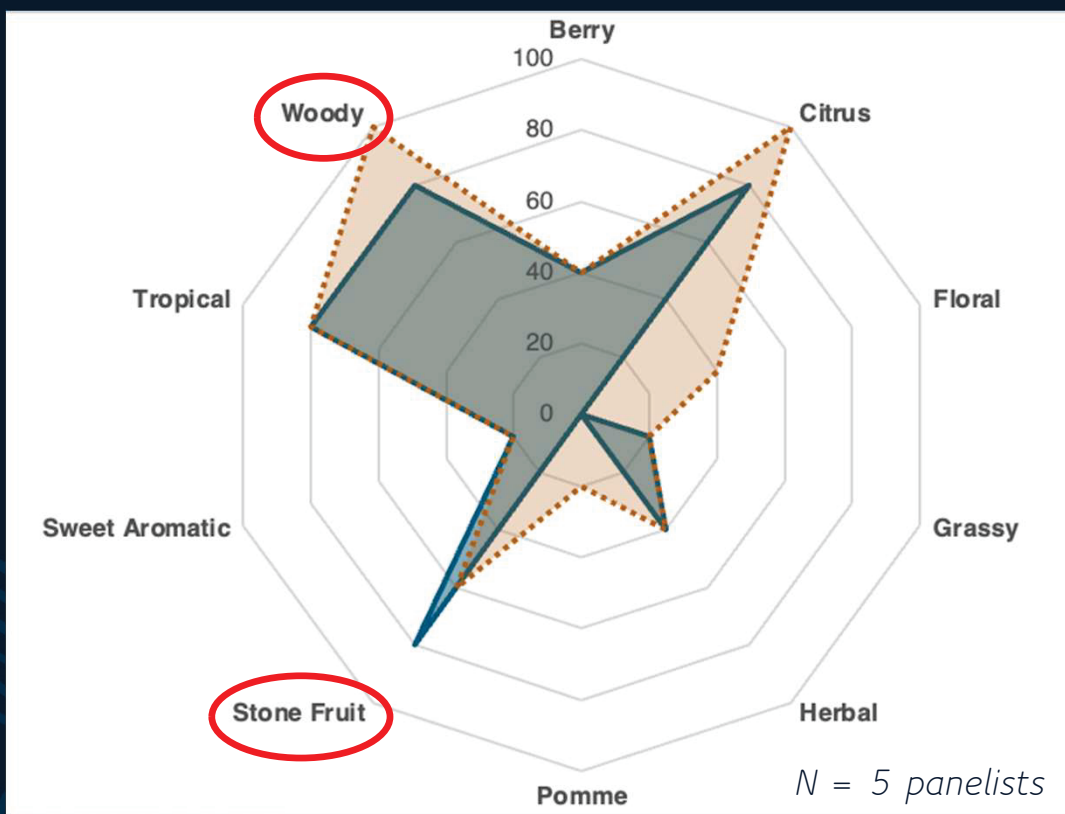
Addition of HyperBoost at a Lower T-90 Dose Increases Total Survivables Compared to a Higher T-90 Dose



Replacement Effect
~50% of the dry hop came from HyperBoost (total 10 g/L T-90 equivalent DH)

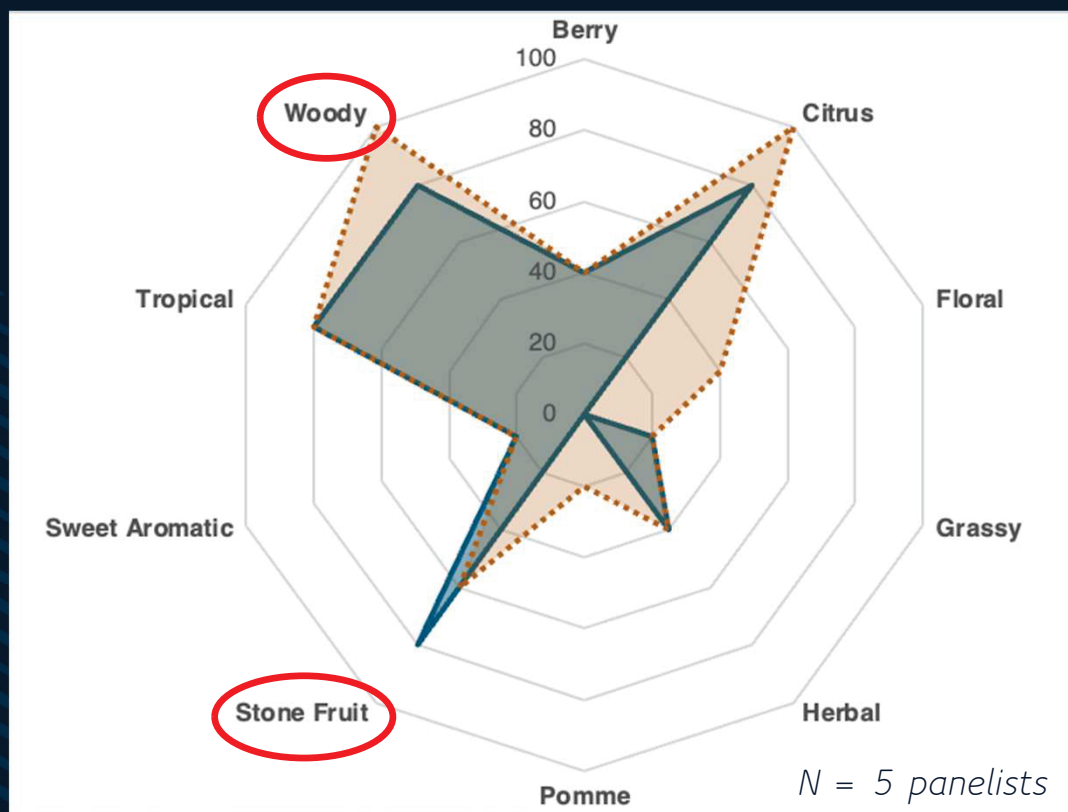
Addition Effect
Additional ~50% of dry hop came from HyperBoost (based on a 10 g/L T-90 DH)

At Equal HB Dose, Higher T-90 Boosts Citrus and Floral – Along with Woody

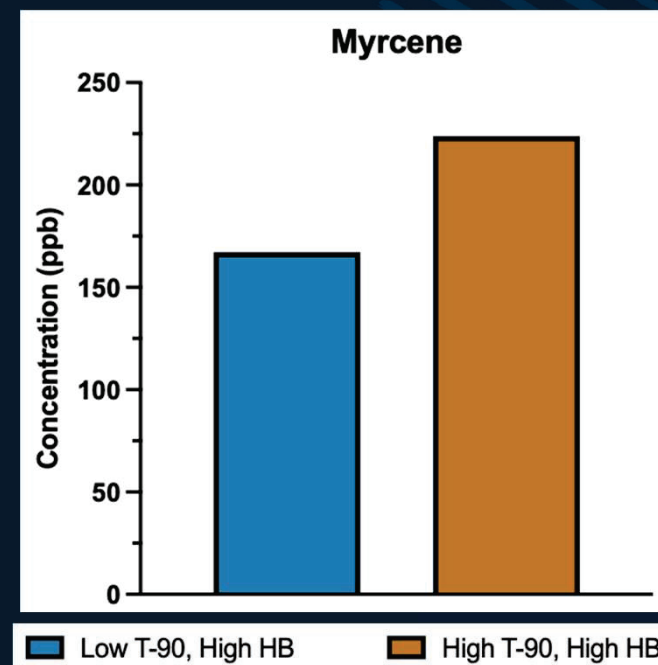


Blue = Low T-90, High HB
Orange = High T-90, High HB

Increased Myrcene Levels with Higher T-90 Dosing May Drive Woody Aroma



Blue = Low T-90, High HB
Orange = High T-90, High HB



Experiment 2 Takeaways

- T-90 dose dominates the aroma profile (again) – HB plays a minor role in shifting the aroma profile.
- HB's impact on survivables profile depends on T-90 dosing – pairing HB with a lower T-90 rate (~50% of dry hop) drives a much larger increase in total survivables than adding HB on top of an already high T-90 dose.
- Matching HB dose across different T-90 levels largely preserves the beer's core sensory profile – though lower T-90 dosing may accentuate stone fruit aromas, and higher T-90 may promote more woody characteristics.

Practical Takeaways

- HB alone is not as effective at delivering impactful aroma profiles compared to T-90 and HB together.
- Combining T-90 and HB can amplify tropical and woody (piney) aromas more than either alone.
- Replacing up to 50% of the dry hop can greatly increase total survivables in the beer.