

# ASBC Annual Meeting

June 4–7 ■ Fort Myers, Florida

*See what SCIENCE can brew for you*

# Hop Flavor & Measuring Quality

Victor Algazzali, M.S.

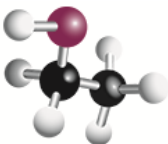
John I Haas, Inc.

06-02-2017

# Hop Flavor & Measuring Quality

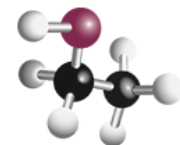
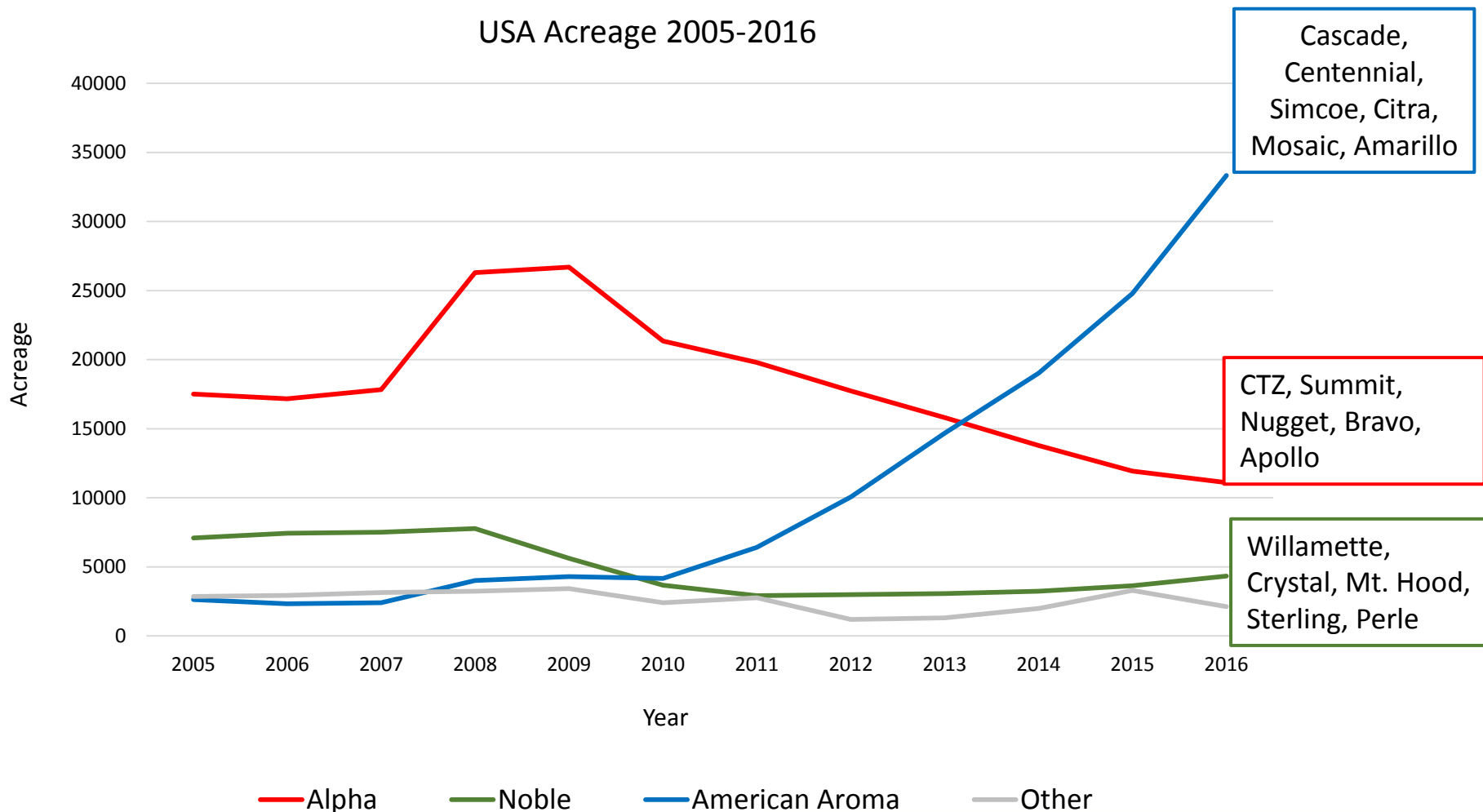
## Content

- I. Flavor of USA variety acreage
- II. Measuring hop flavor quality
- III. Chemical components of hop flavor
- IV. Exercise 1: Smelling hop oil components
- V. Beer and hop chemistry
- VI. Exercise 2: Beer tasting – hop forward beers





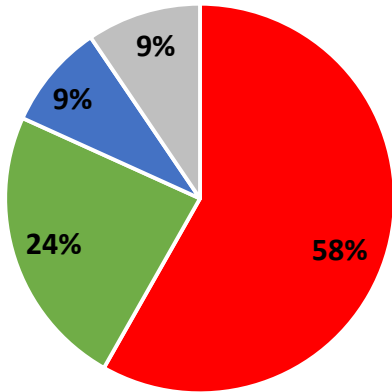
# Shift in acreage from Alpha to Aroma





# Shift in flavor of aroma varieties

2005



■ Alpha ■ Noble ■ American Aroma ■ Other

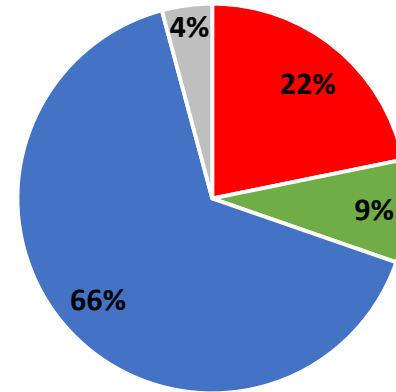


CTZ, Summit,  
Nugget, Bravo,  
Apollo

Willamette,  
Crystal, Mt. Hood,  
Sterling, Perle



2016



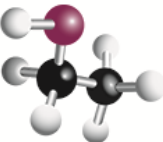
■ Alpha ■ Noble ■ American Aroma ■ Other



Cascade,  
Centennial,  
Simcoe, Citra,  
Mosaic, Amarillo



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# Ever increasing number of hop varieties

Number of US aroma varieties tracked by acre in HGA report

2005

2016

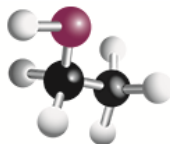
**14 vs 26**

Number of commercial varieties reported with sensory data in the 2017 *Variety Snapshot*...

**69**



- ❖ We may have more than 100 commercial hop varieties in the USA
- ❖ Flavor differentiation or repeating flavors?
- ❖ How many varieties is sustainable?

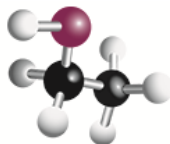


# Keeping track of hop flavor quality

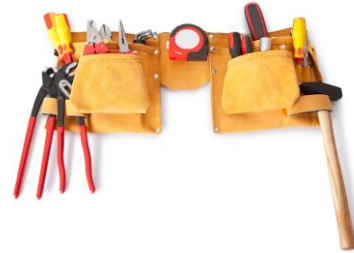


## Factors that may affect hop quality

- Growing region and climate
- Harvest window
- Kilning and pelletizing conditions
- Packaging and storage conditions
- Genetic drift and cross pollination

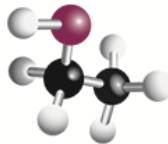
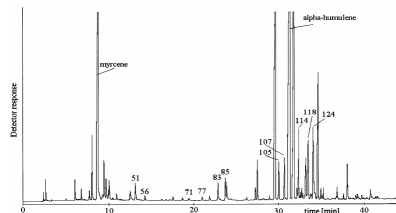
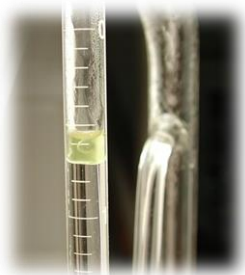


# Measuring hop flavor quality - tools

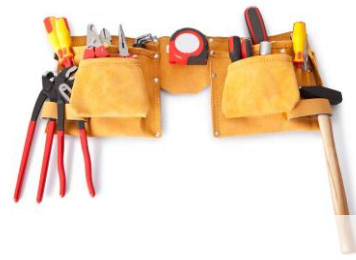


## Chemical Analysis

## Sensory Analysis

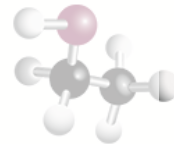
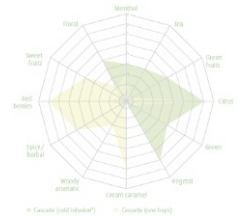
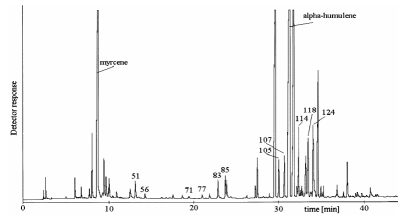
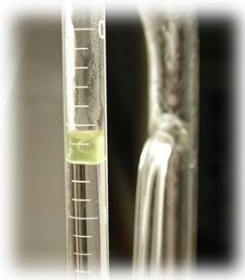
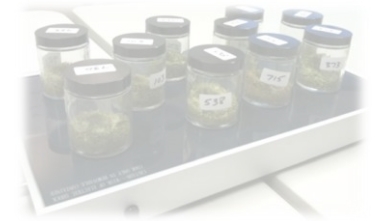


# Measuring hop flavor quality - tools



## Chemical Analysis

## Sensory Analysis

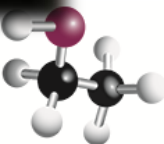
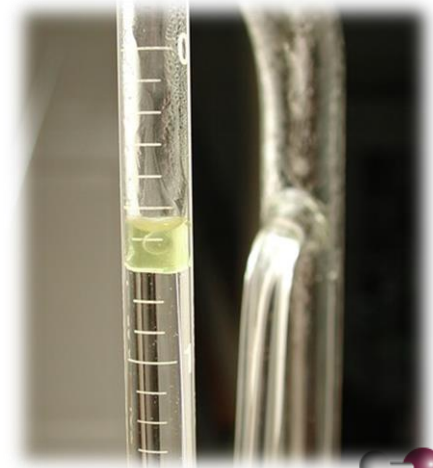




# Chemical Analysis – Total oil method

- ASBC Method Hops-13
- Bread and butter tool to quantify hop oil
- Steam distillation of hop material to quantify oil fraction (ml oil/100mg hops)
- Gives you a single number, typically 1.0 - 4.0 ml/100g

5k – 100k



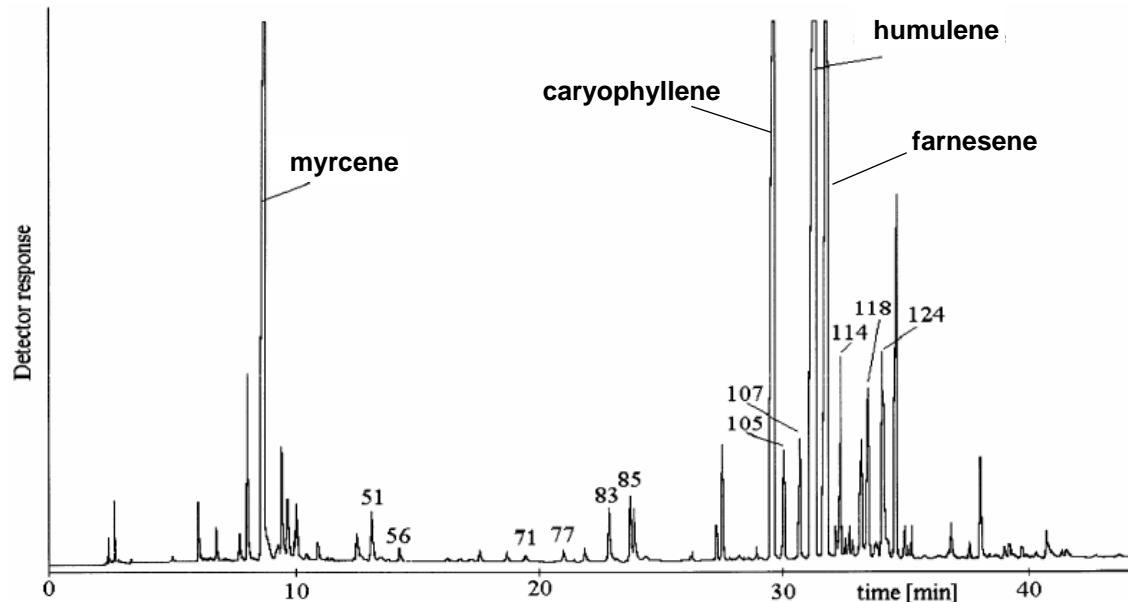
# Chemical Analysis of hop oil – Gas Chromatography

A technique to:

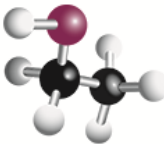
1. Split up hop oil components based on chemical and physical properties.
2. Measure the quantity of split components

20k – 100k  


ASBC Method Hops - 17



SBC Meeting



# Which Oils are important?

The Big 4 oils	Willamette	Chinook
Myrcene	38%	35%
Humulene	21%	23%
Caryophyllene	10%	8%
Farnesene	1%	5%

## Willamette

Washington/  
Oregon



Grassy, herbal, tea,  
woody

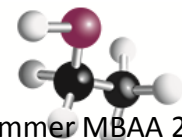
## Chinook

Washington/  
Oregon



Citrus, pine,  
grapefruit, fruity

- A large proportion of hop oil does not explain the differences in hop flavor.
- “The Big 4 oils“ are still the bread and butter hop oil quality measurement.
- The Big 4 oils are decent fingerprinting hop oil quality metric



# Which Oils are important?

**Table 1.** Comparison of analytical properties of hop varieties Citra, Hallertauer Tradition, and Nelson Sauvin

Variable (unit)	Citra	Hallertauer Tradition <sup>a</sup>	Nelson Sauvin <sup>b</sup>
$\alpha$ -Acids (% of cone wt)	11–13	4.0–7.0	12–13
$\beta$ -Acids (% of cone wt)	3.5–4.5	3.0–6.0	6–8
Cohumulone (% of $\alpha$ -acids)	22–24	24–30	24
Total oil (mL/100 g cones)	2.2–2.8	0.5–1.0	1.0–1.2
Myrcene (% of total oil)	60–65	17–32	21–23
Humulene (% of total oil)	11–13	35–50	35–37
Caryophyllene (% of total oil)	6–8	10–15	10–12
Linalool (% of total oil)	1–2	0.7–1.2	0.8
Farnesene (% of total oil)	<1	<1	0.4
Storage stability (relative retention of $\alpha$ -acids)	Fair	Good	Good

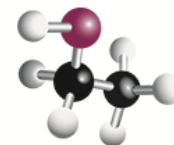
<sup>a</sup> Source: Deutscher-Hopfen (4).

<sup>b</sup> Source: New Zealand Hops Limited (18).

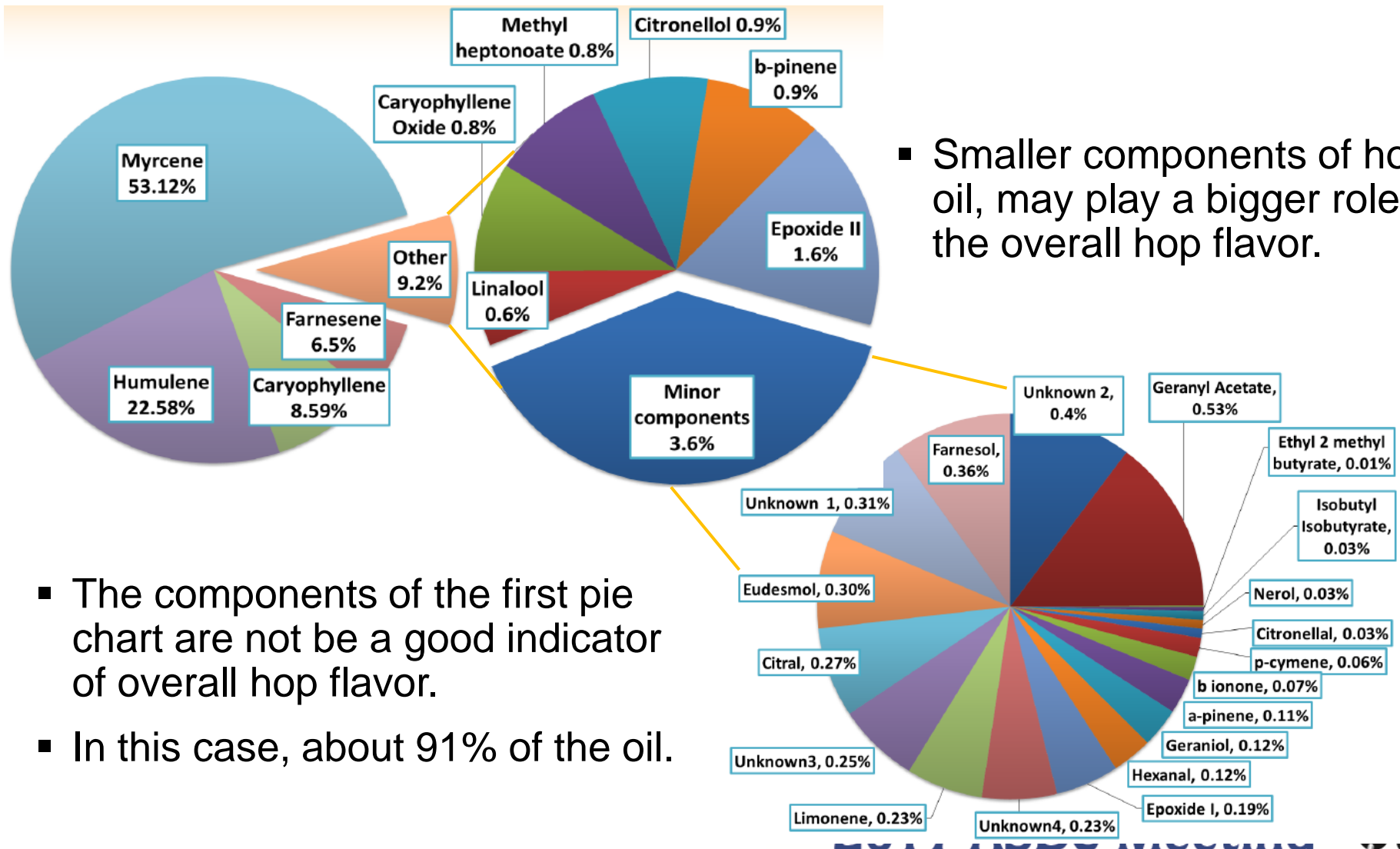


Similar

- This oil data show close similarity between Hallertauer Tradition (a noble-flavor German variety) and Nelson Sauvin (a fruity-flavor Australian variety).
- The data shows little similarity between Citra and Nelson Sauvin, despite them arguably smelling more similar, both being fruity-flavored hop varieties.

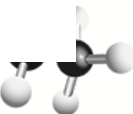


# A look into the minor components of hop oil



- The components of the first pie chart are not be a good indicator of overall hop flavor.
- In this case, about 91% of the oil.

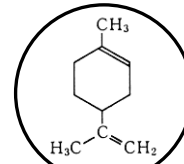
- Smaller components of hop oil, may play a bigger role in the overall hop flavor.



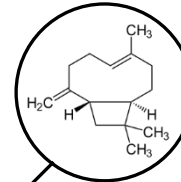
# Hydrocarbons

Sesquiterpenes

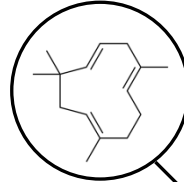
Limonene



Caryophyllene

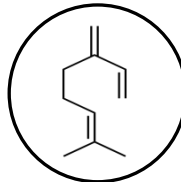


Humulene



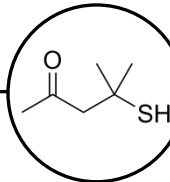
Terpenes

Myrcene



Hops

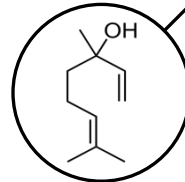
4-MMP



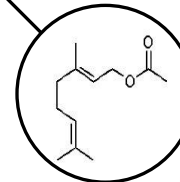
Sulfurs

Thiols

Linalool

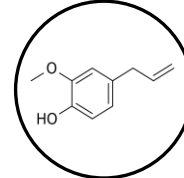


Geranyl Acetate



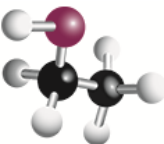
Terpene alcohols

Eugenol

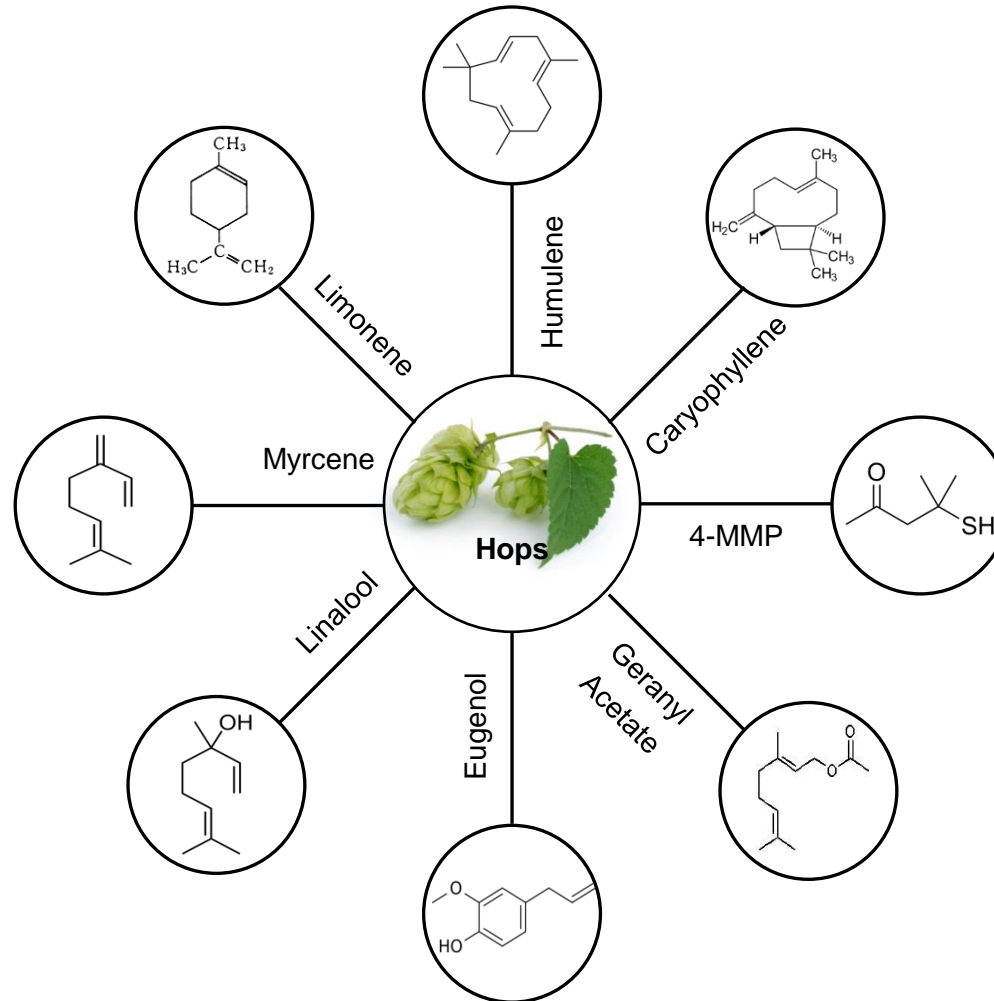


Esters

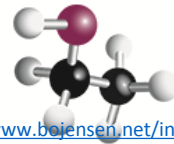
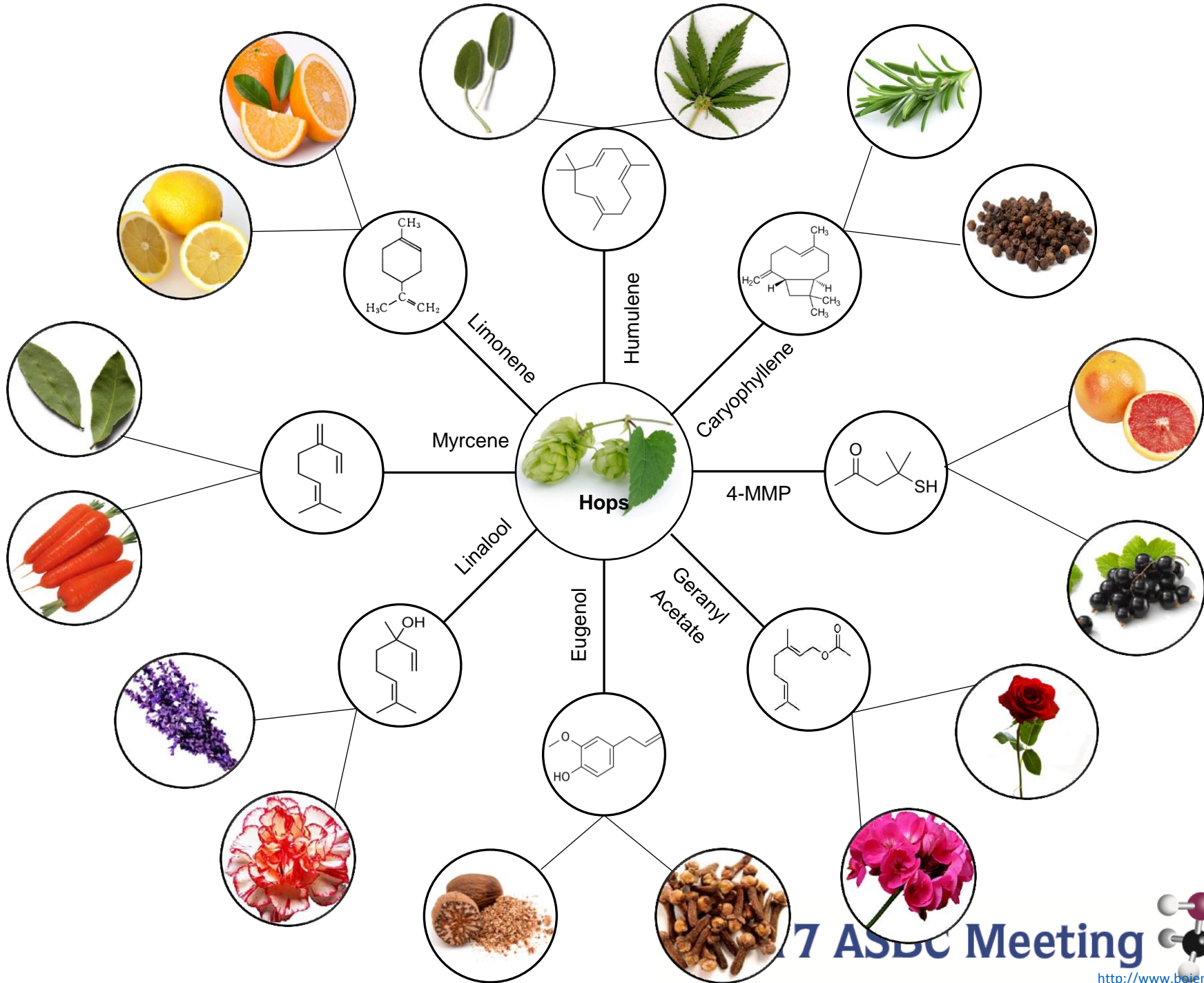
Oxygen Containing Compounds 2017 ASBC Meeting



# Hop oil Evaluation Exercise



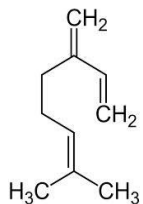
Smell each component. Take notes on flavor.







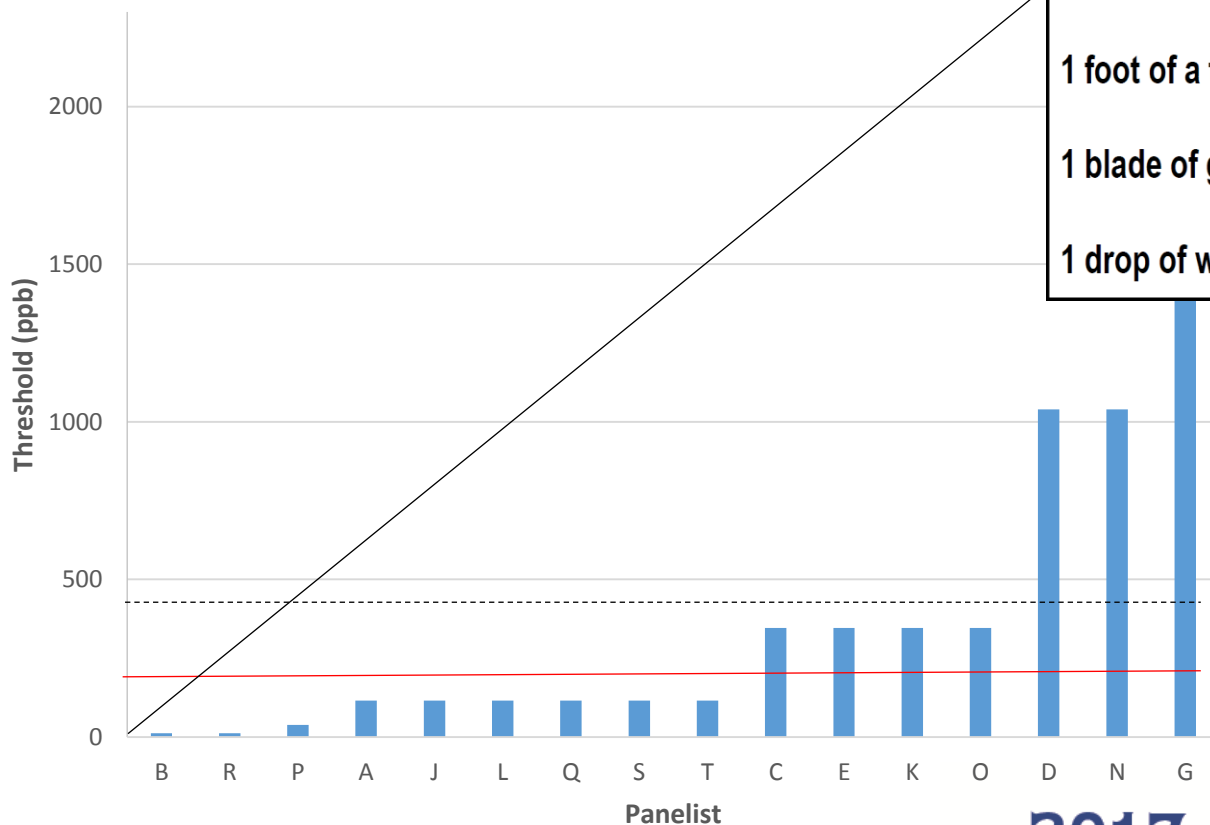
# Threshold Testing in beer at John I Haas



**Myrcene** – spiked in beer



Panelist's Threshold of Detection



**Some real-world part per billion comparisons**

1 penny in 10 million dollars

1 second in 32 years

1 foot of a trip to the moon

1 blade of grass on a football field

1 drop of water in an Olympic-size swimming pool

----- Panel average

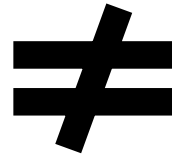
— Published average

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# Brewing – Hop flavor in beer

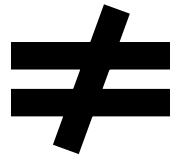
Hop aroma



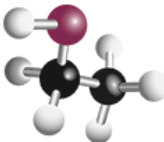
Beer aroma



Coffee bean aroma



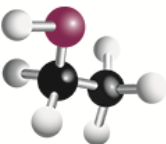
Coffee aroma



Why is Hop aroma   $\neq$  Beer aroma  ?

## Many possible explanations

- Hops are very concentrated in oil. Perception of oil flavors change with concentration
  - At lower concentrations in beer, the flavor may change
- Each component of hop oil has a different solubility chemistry in beer - *Terpenes vs. Terpene Alcohols*
  - The components in hops may not be present in beer
- Hops contain components that are not are not flavor active until after the brewing process – *glycosides*
- Hop flavor compounds change as they endure the chemistry of brewing - heat, pH, enzymatic reactions, yeast biotransformation, oxidation, and time.



# Predicting hop flavor in beer with chemistry

## The lifelong pursuit

Mission impossible

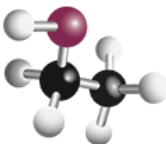
Golden Fleece

The holy grail

## Many Challenges

- Correlating sensory data and GC data – lots of data
- Expertise and technical knowledge
  - Chemistry, Instrumentation, Sensory Analysis, Statistics
- Human resources & long project timelines
- Expensive equipment
- Technology detection limits are still behind the human nose
  - The human nose can detect odors in parts per trillion
  - Sulfur compounds
  - Unidentified compounds

**100k – 500k**



# Many hop chemistry theories to work on...

Does more hop oil equal more beer flavor?

- Vollmer, Shellhammer 2016

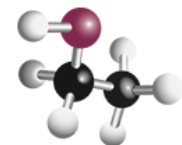
Oxidation of hop oil - is it objectively bad?

-Vollmer, Algazzali, Shellhammer 2017

What is the impact of hop glycosides on beer flavor?

-Sharp, Vollmer, Qian, Shellhammer 2017

What is the impact of sulfur compounds on beer flavor?

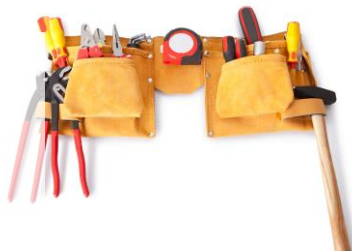


# Measuring hop flavor quality - tools

10k – 1.0M



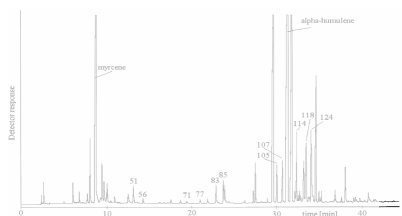
Chemical Analysis



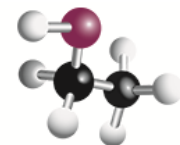
10k – 100k



Sensory Analysis



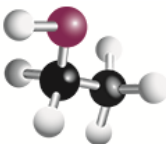
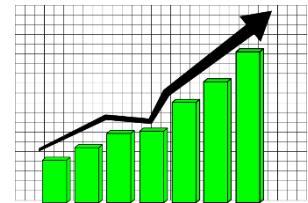
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# Sensory Science



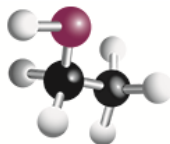
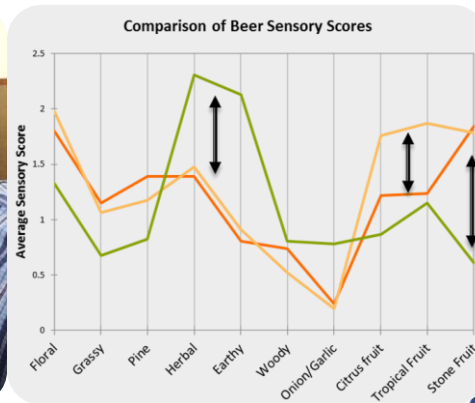
The use of human subjects as instruments of perception to evaluate products with the goal of generating data to make meaningful conclusions.







- A tool to measure hop quality and flavor
- Identify new hop flavors, and match existing hop flavors
- Measure the effect of brewing and processing on hop flavor
- Establish cause and effect relationships



# Beer Evaluation Exercise

## Goal:

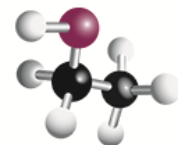
- Taste beers with a diversity of hop flavor, targeting different flavor buckets.

Smell and taste the beers. Afterwards we will discuss flavor, overall intensity, and hop varieties.

- Beer 1
- Beer 2
- Beer 3
- Beer 4



Beer 2, 3, 4 each showcase a single hop variety!

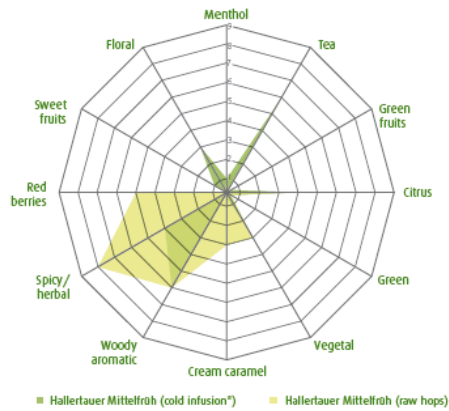


# Beer 1

- Beer Style: Pilsner
- Origin: Pennsylvania
- Hop Variety: Hallertauer and Tettnanger

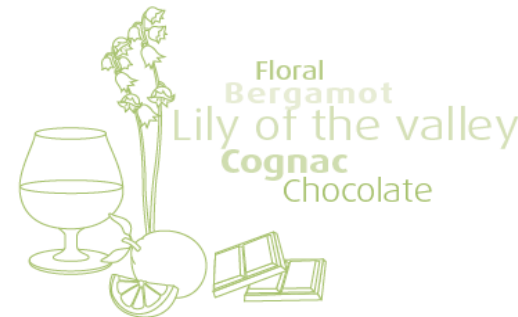


Hallertauer  
Mittelfrüh  
Germany

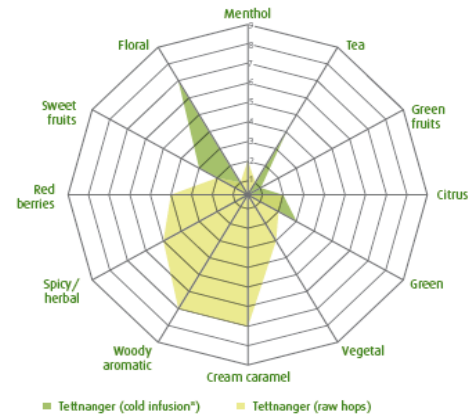


Hallertauer Mittelfrüh is the original regional variety of Hallertau and, with its delicate aroma and average bitter content, is still very popular today.

This hop variety almost disappeared due to its high susceptibility to wilt. Thanks to a resurgence in demand and newly available virus-free plants, however, the cultivar is currently making a comeback. The flavour profile of the Hallertauer Mittelfrüh in its raw state is characterised by spicy, woody aromas, such as liquorice and hay, with slight notes of blackberries. In the

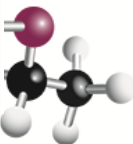


Tettnanger  
Germany



Tettnanger is a traditional domestic cultivar belonging to the Saaz family and is grown exclusively around Tettngang near Lake Constance.

In this region, the unique combination of favourable climate and loamy soil provide for a very fine aroma. The Tettnang hop displays good resistance to all plant diseases. In the raw hops, woody aromas and cream-caramel components, such as gingerbread and almonds, predominate, combined with fruity blueberry notes. In the cold infusion, floral notes and



# Beer 2

- Beer Style: Pale Ale
- Origin: California
- Hop Variety: Cascade



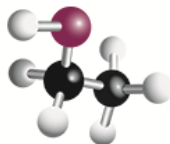
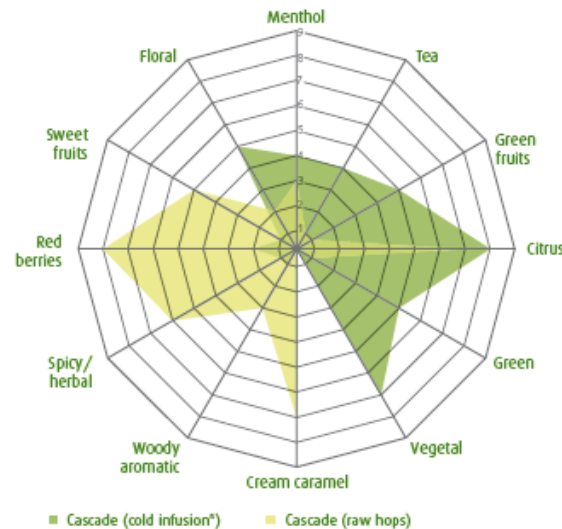
## Cascade

Washington/  
Oregon



The Cascade mountains, with their volcanic origins, give the cultivar of the same name its medium-strong, very distinct, fragrant floral aroma.

The main features of this variety are its long, dark-green cones and its low alpha content. In the cold infusion, citrus aromas come strongly to the fore, whereas cream-caramel and fruity notes of blackberries and mango predominate in the raw hops. Due to its optimal cultivation characteristics and good resistance to downy mildew, Cascade is a high-yielding



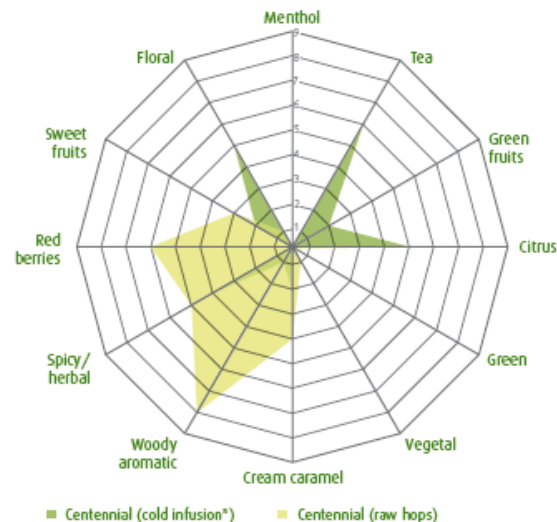
# Beer 3

- Beer Style: IPA
- Origin: Michigan
- Hop Variety: Centennial



## Centennial

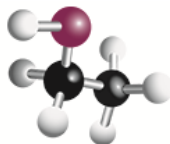
Washington/  
Oregon



Centennial is a relatively new high-alpha variety. First released in 1990, Centennial is composed of  $\frac{3}{4}$  Brewers Gold and minor shares of other cultivars, such as Fuggle and East Kent Golding.

Sometimes it is also referred to as Super Cascade, but the citrus character that predominates in Cascade is not as strongly noticeable in Centennial. In the raw hops, woody-spicy aromas of spruce, barrique, tonka bean, tarragon and aniseed combine with fruity raspberry notes to produce a well-rounded character.

Meeting



# Beer 4

- Beer Style: Pale Ale
- Origin: Idaho
- Hop Variety: Citra



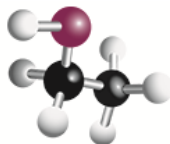
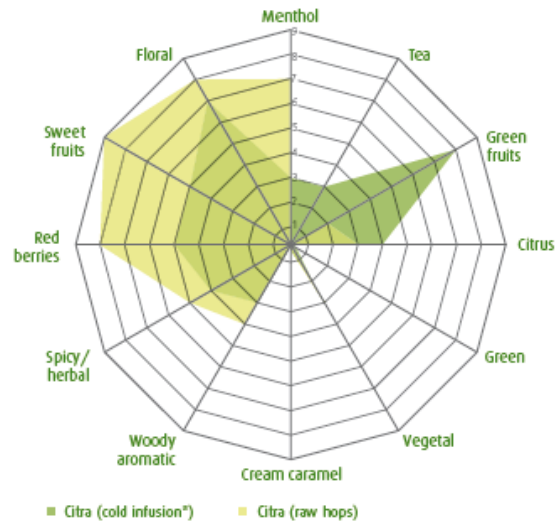
## Citra

Washington/  
Oregon



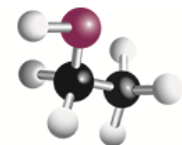
Citra is an aroma hop variety with a promising future. Developed by the hop-breeding company LLC, it has unique and captivating flavour characteristics.

As its name suggests, Citra's flavour profile contains citrus fruits, such as lime and grapefruit, which are particularly pronounced in the cold infusion. However, tropical fruit notes of passion fruit, peach, lychee and many others also contribute to its uniquely fruity aroma. In the cold infusion, floral to spicy characteristics predominate, rounding off the flavour



# Concluding Thoughts

- Increased value on aroma varieties and hop forward beers will increase demand for flavor quality analysis
- Hop flavor chemistry research is evolving with lots of potential. There are many questions to still answer
- Sensory analysis is a fundamental tool for measuring hop flavor quality



**Thank you for listening**

Questions?