



## Dry hopping contributions to bitterness

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### How to assess bitterness?

## Overview

- How to assess bitterness
- Contributors to bitterness
- BU deviations at high hopping rates
- Dry hopping experiments

## The IBU Analysis

Liquid-Liquid extraction of bitter compounds from beer

Beer

**Bitter compounds**  
Iso alpha acids  
Oxidized hop acids  
Polyphenols  
**Non-bitter compounds**  
Alpha acids

Strong Acid

+ Adds excess hydrogen ions to solution – protonating all carboxylic acid functional groups

Non-Polar Solvent

+ When functional groups are protonated at a lower pH molecules decrease in polarity

3 N Hydrochloric Acid

2,2,4 trimethylpentane

## The IBU Analysis

Measure the absorbance at 275 nm

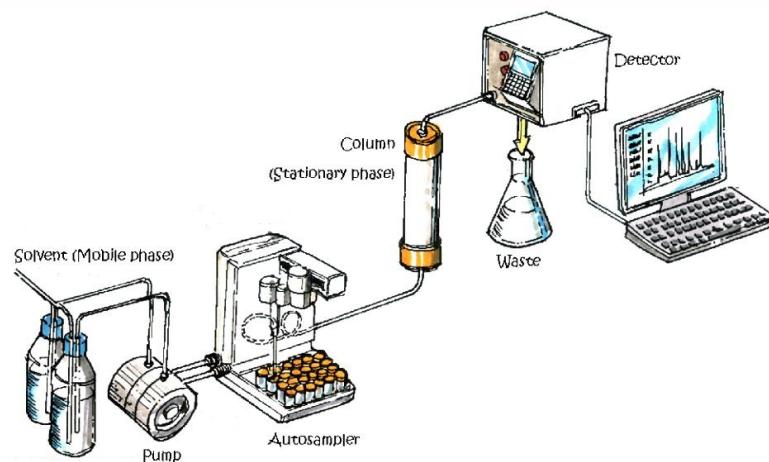
$$\text{Absorbance @}275 \times 50 = \text{Bittering Units}$$

1 BU  $\neq$  1 ppm iso-alpha acid

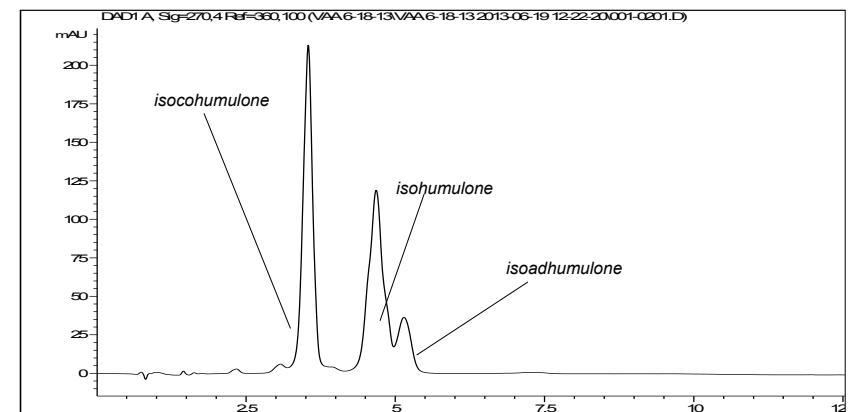
## What does the BU measure?

- Whatever gets extracted by iso-octane
- Whatever absorbs at 275 nm.
- Combined  $\alpha$ ,  $\beta$ , iso's, oxidized materials, polyphenols
- 1 BU  $\neq$  1 ppm iso-alpha acid

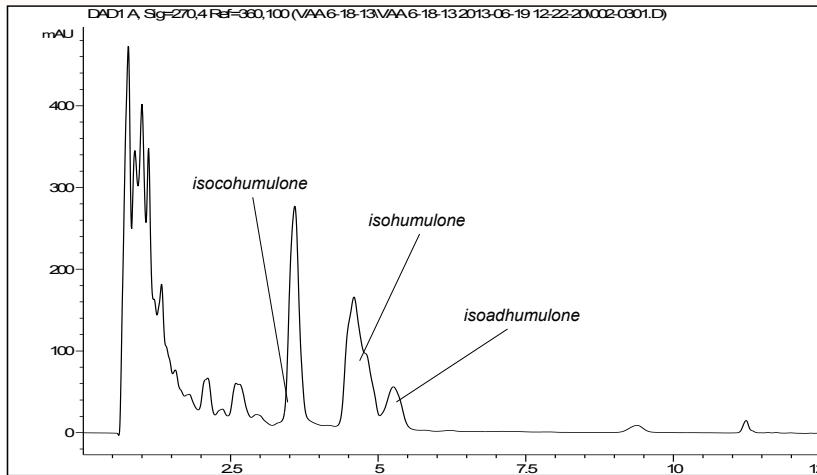
## HPLC (Liquid Chromatography)



## Standard iso-alpha acid



## Beer Sample



## Sensory assessment of bitterness

- Difference tests
  - Triangle tests
  - Paired-comparisons
  - Difference from control
- Time-intensity
- Descriptive

## Sensory evaluation

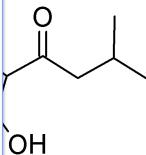
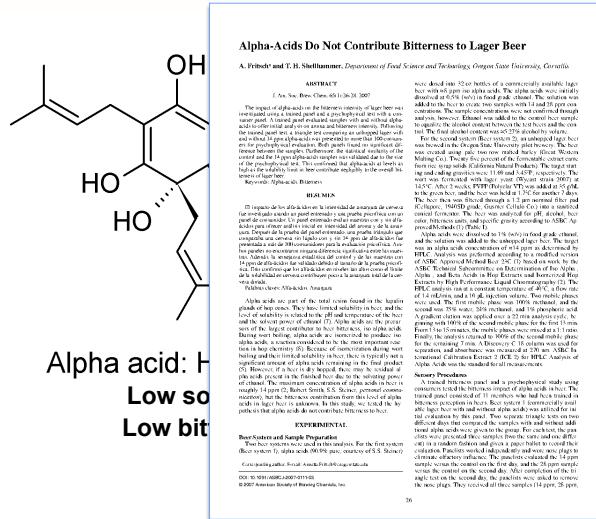


Eliminate olfactory influences – nose clips

Eliminate visual cues - opaque serving cups, attention to pouring

## Contributors to bitterness

## Thermal isomerization of alpha acids produces iso-alpha acid bitterness

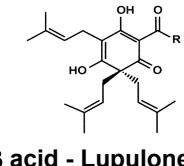
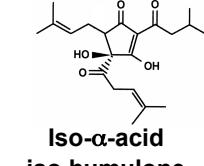


**sohummulone**

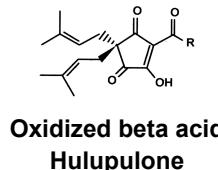
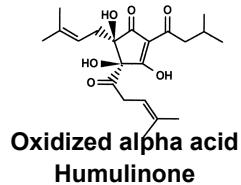
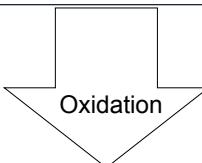
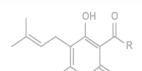
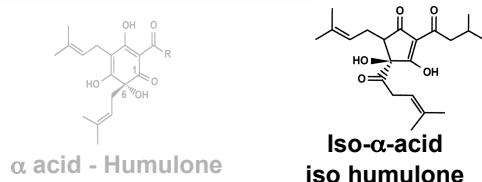
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## $\alpha$ and $\beta$ acid oxidation



## $\alpha$ and $\beta$ acid oxidation

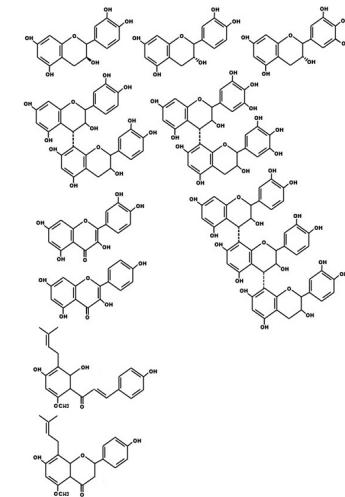


## Hop polyphenols

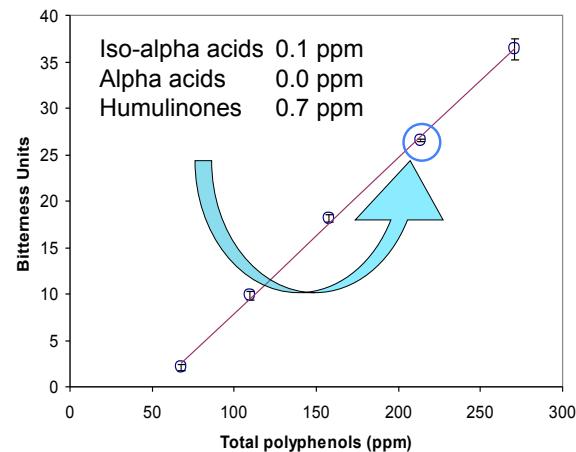
Extraordinarily diverse group of compounds found in all plant material.

Characterized by a number of aromatic rings with numerous substituted hydroxyl groups.

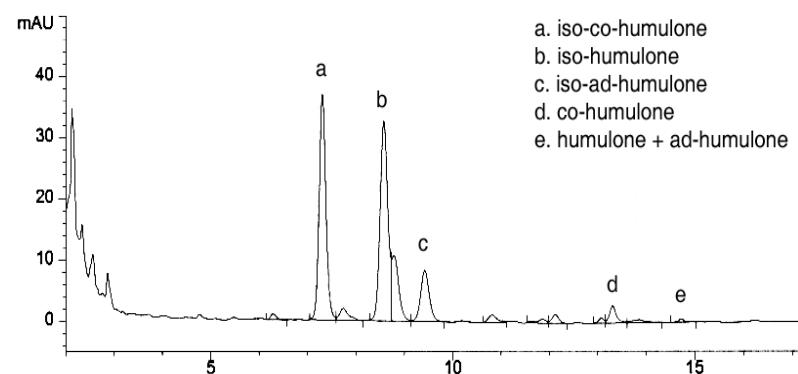
Polyphenols are highly reactive, easily oxidized and polymerized into high MW tannins.



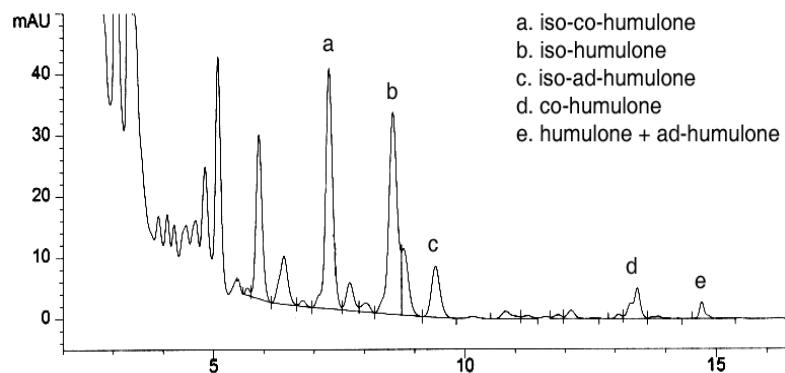
## BU increase due to hop polyphenols



## Lightly kettle hopped beer

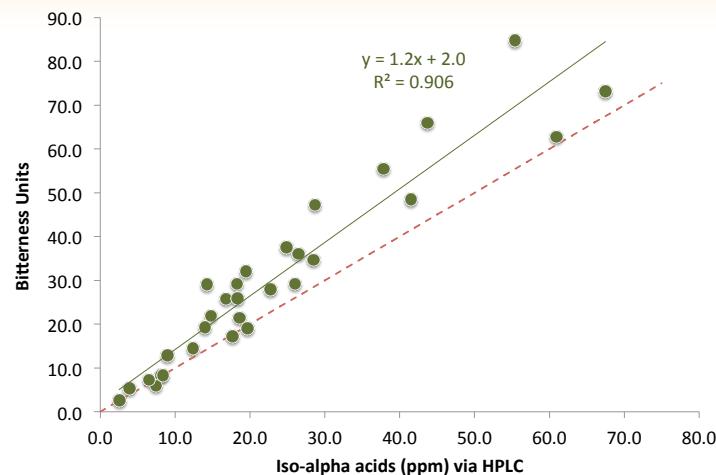


## Heavily dry-hopped beer

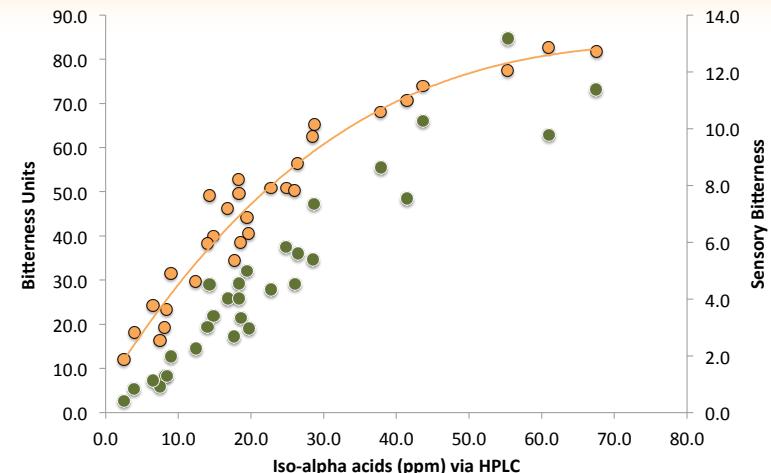


## BU deviations at high hopping rates

## Correlation between total IAA & IBU



## Sensory bitterness does not track BU/IAA



## Dry hopping experiments

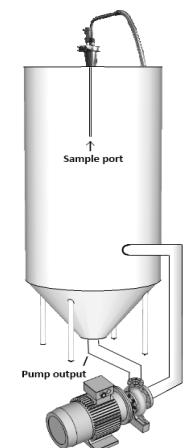
### Dry hopping experiment 1 with Cascade hops

#### Experimental set up

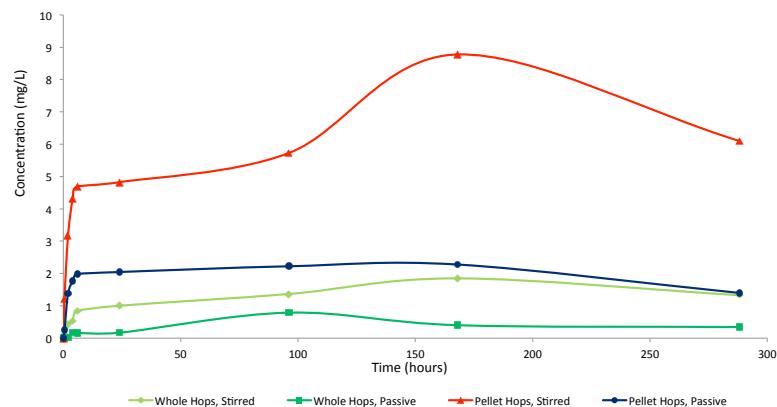
- 90 Gallons (340 Liters) of beer in each treatment
- 1 lb/barrel (386g/hL) hops used for each treatment
- One CCV utilized a centrifugal pump for stirring

#### Factors

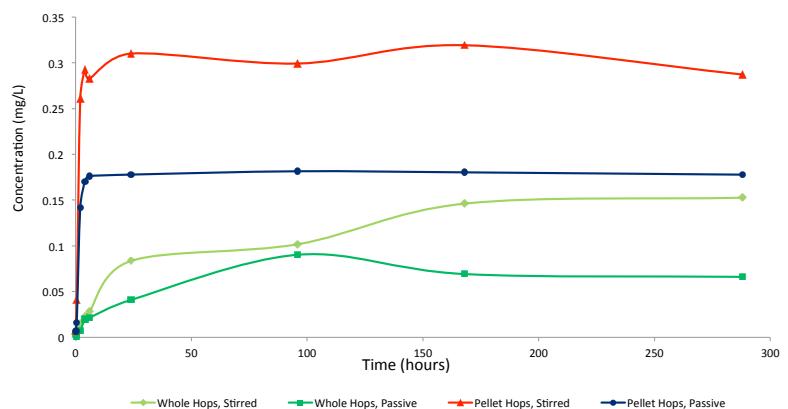
- Hop form – whole vs. pellets
- Mixing – agitated vs. quiescent



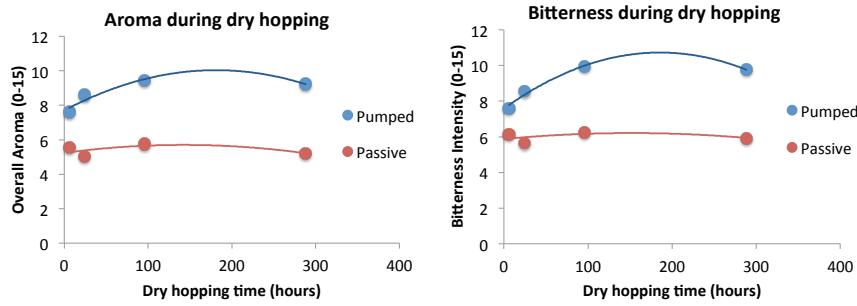
## Results - Myrcene



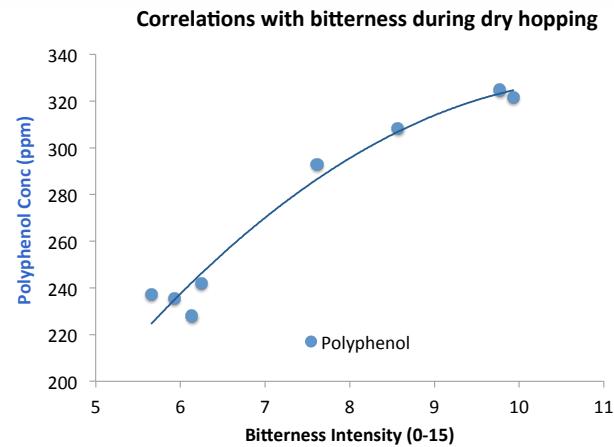
## Results - Linalool



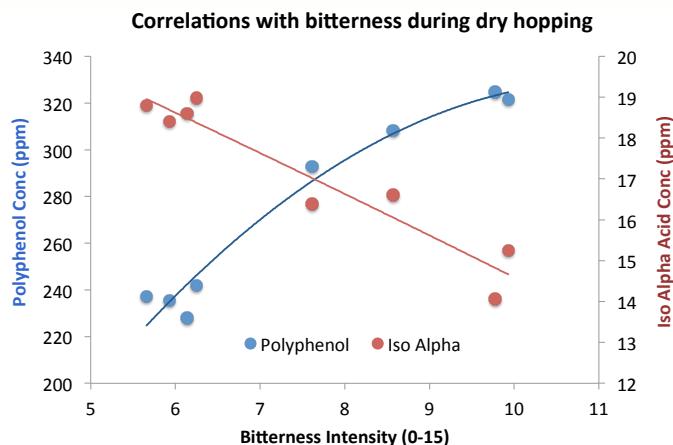
## Dry hopping study with Cascade pellets



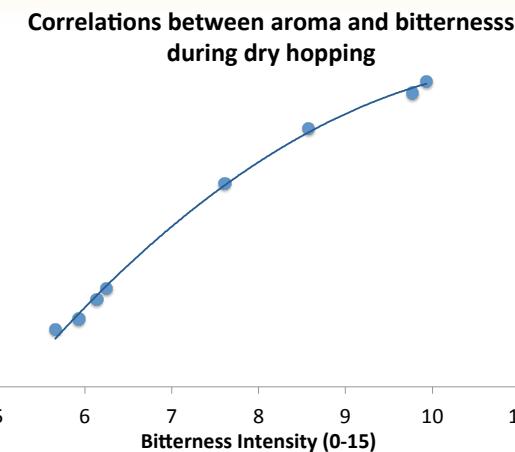
## Dry hopping study with Cascade pellets



## Dry hopping study with Cascade pellets



## Dry hopping study with Cascade pellets



## Dry hop experiment 2 with Chinook

### Dry hopping parameters

- 10 L unhopped beer, filtered
- 4 g/L and 16 g/L
- Quiescent, cold, up to 4 days

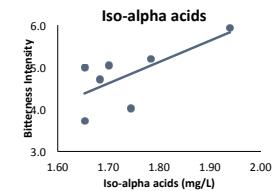
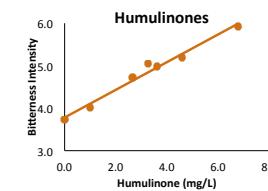
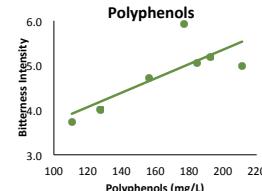
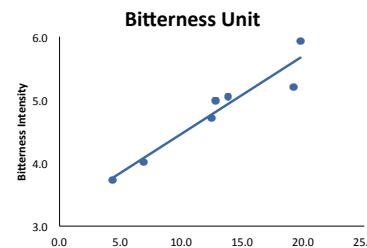
### Sensory protocol

- 11 panelists
- Scaling bitterness and aroma intensity (0-9), 6 reps

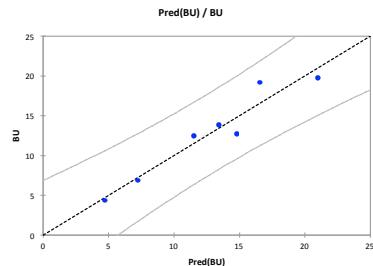
### Instrumental analyses

- Hop acids – HPLC
- Polyphenols
- Bitterness Units

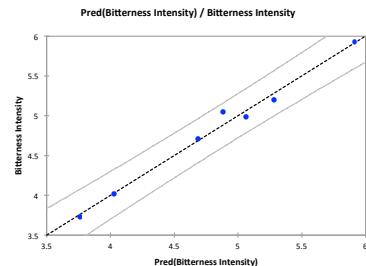
## Contributions to bitterness intensity



## Contributing factors to dry hop bitterness



$$\text{BU} = 2.3 + 0.02 \times [\text{PP}] + 2.20 \times [\text{Humulinones}]$$



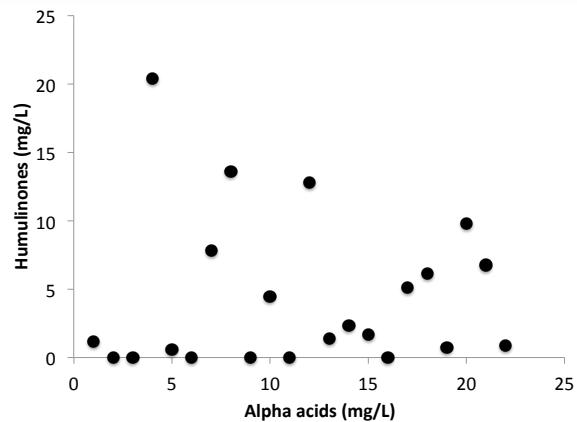
$$\text{Bitterness Intensity} = 5.5 - 1.0 \times [\text{IAA}] + 0.4 \times [\text{Humulinones}]$$

## Commercial beer screening

- 22 commercial beers screened

Compound	Min (mg/L)	Max (mg/L)
Alpha acids	0	2.6
Iso-alpha acids	8.8	70.3
Humulinones	0	20.3 (n=16)
Hulupulones	0	2.0 (n=1)

## Commercial beer screening



## Conclusion

- Dry hopping contributes bitterness to beer
- Sources - **not** alpha and/or iso-alpha acids
- Contributors may be
  - Polyphenols
  - Oxidized hop acids
  - Oil
- Bitterness increases in dry hop beer may correlate with dry hop aroma