



## 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



## The IBU Analysis

Measure the absorbance at 275 nm

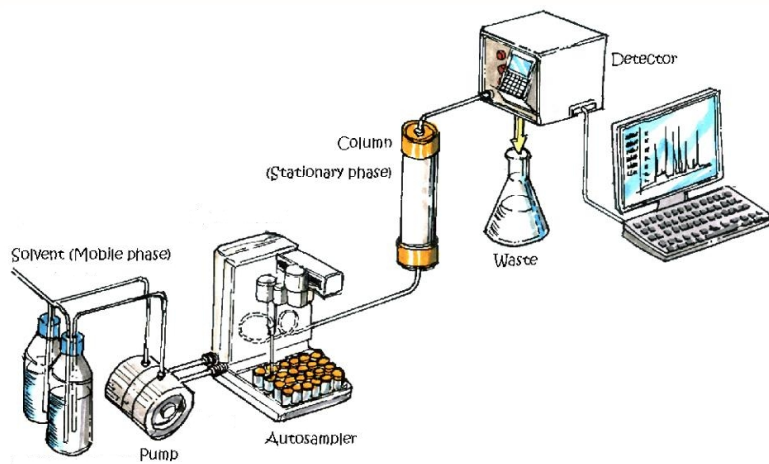
Absorbance @275 x 50 = *Bittering Units*

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

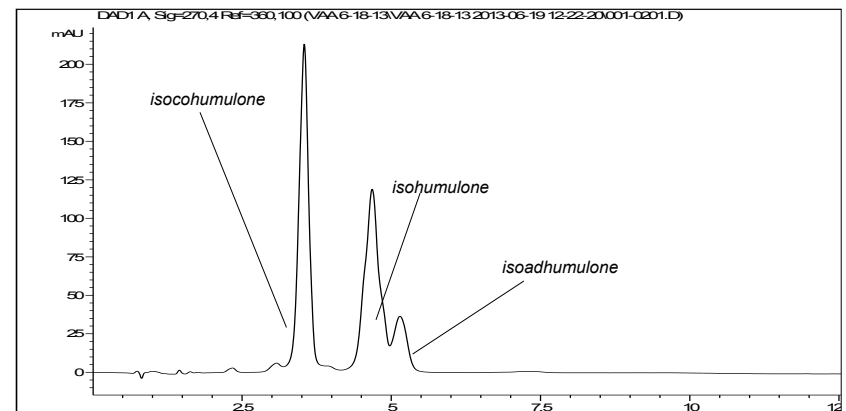
## What does the BU measure?

- 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

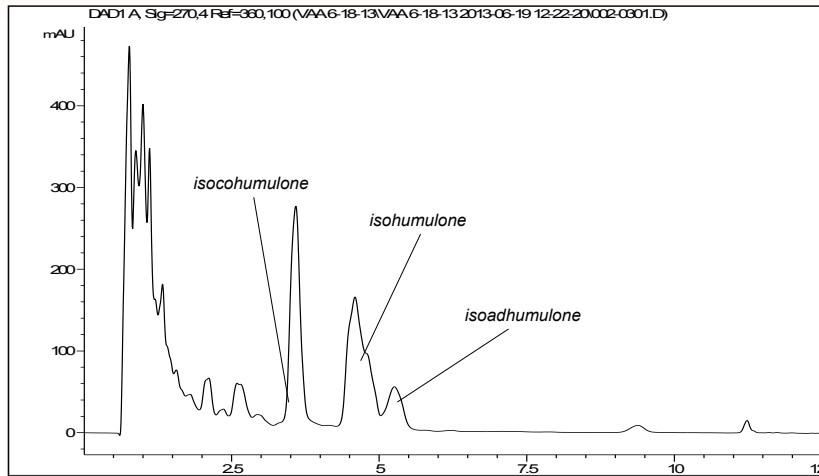
## HPLC (Liquid Chromatography)



## Standard iso-alpha acid



## Beer Sample



## Sensory assessment of bitterness

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

## Sensory evaluation



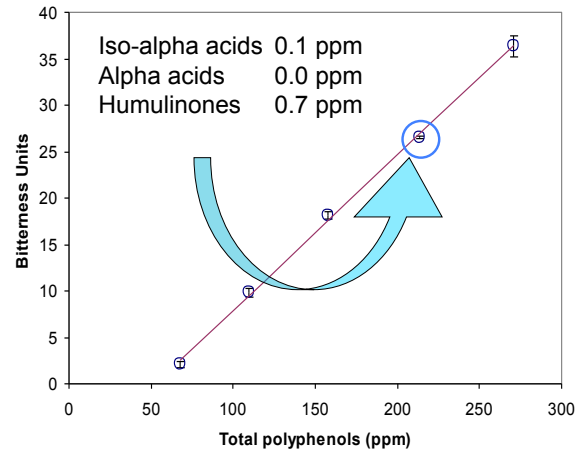
Eliminate olfactory influences – nose clips

Eliminate visual cues - opaque serving cups, attention to pouring

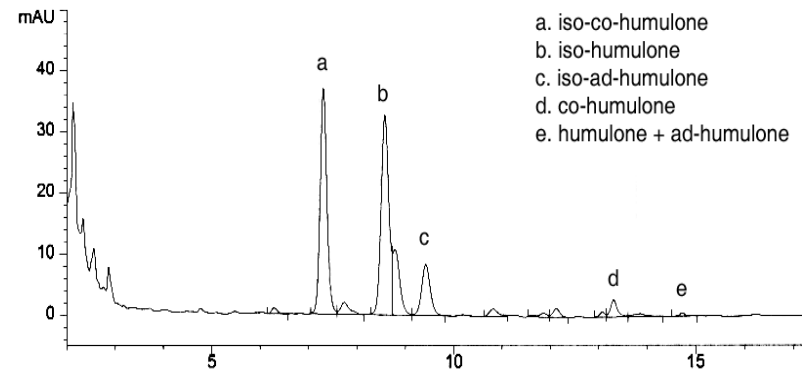
## Contributors to bitterness



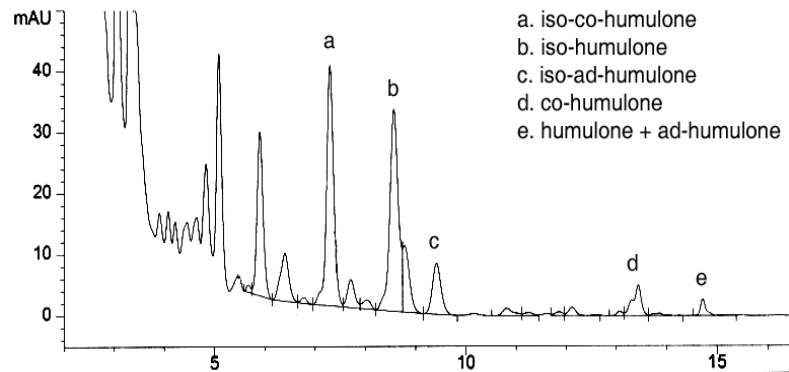
## BU increase due to hop polyphenols



## Lightly kettle hopped beer

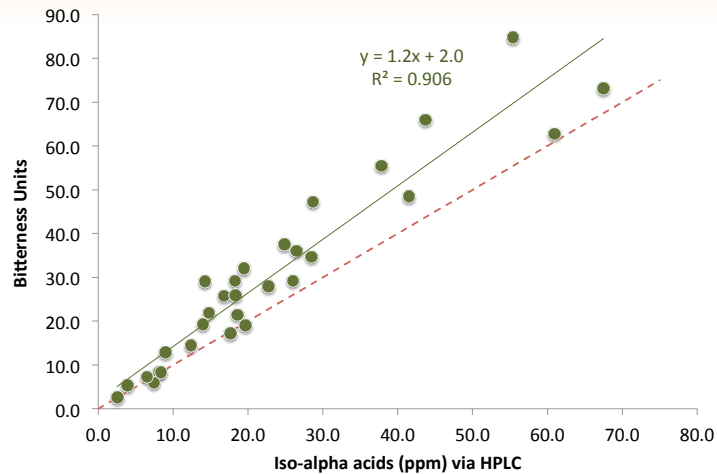


## Heavily dry-hopped beer

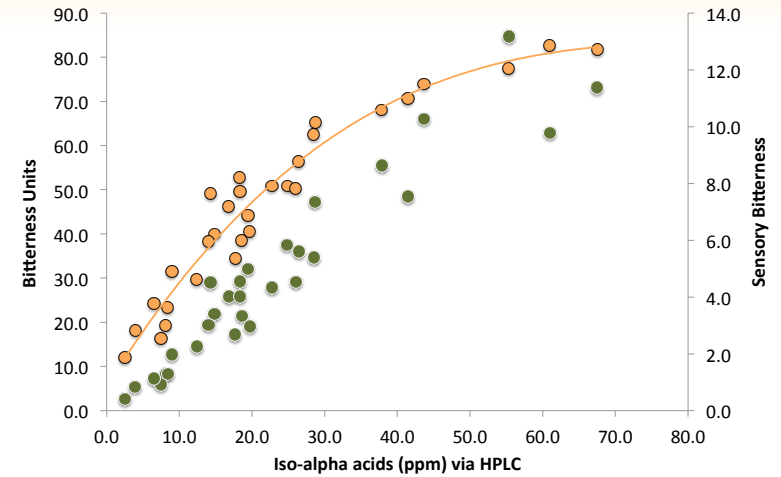


## BU deviations at high hopping rates

## Correlation between total IAA & IBU



## Sensory bitterness does not track BU/IAA



## Dry hopping experiments

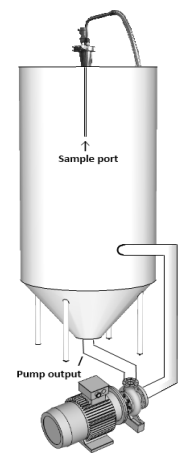
## Dry hopping experiment 1 with Cascade hops

### Experimental set up

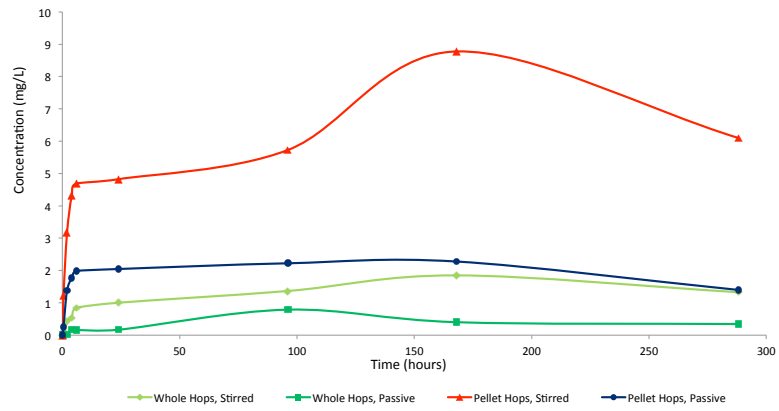
- 90 Gallons (340 Liters) of beer in each treatment
- 1 lb/barrel (386g/hL) hops used for each treatment
- One CCV utilized a centrifugal pump for stirring

### Factors

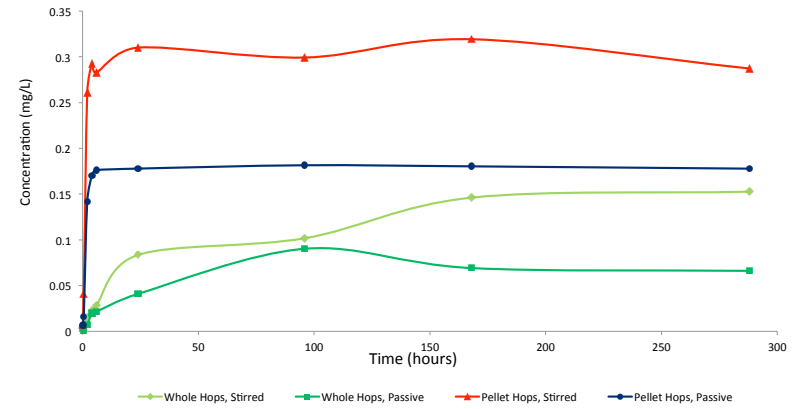
- Hop form – whole vs. pellets
- Mixing – agitated vs. quiescent



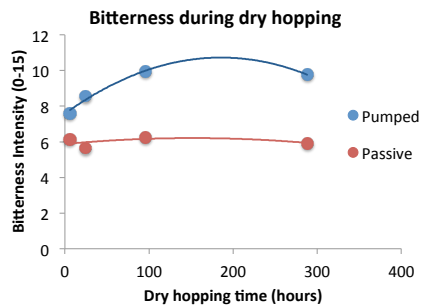
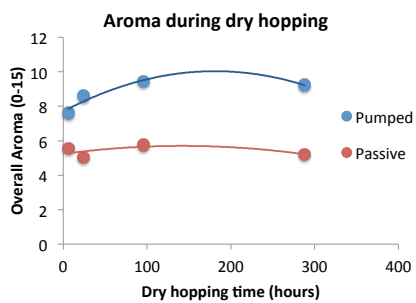
## Results - Myrcene



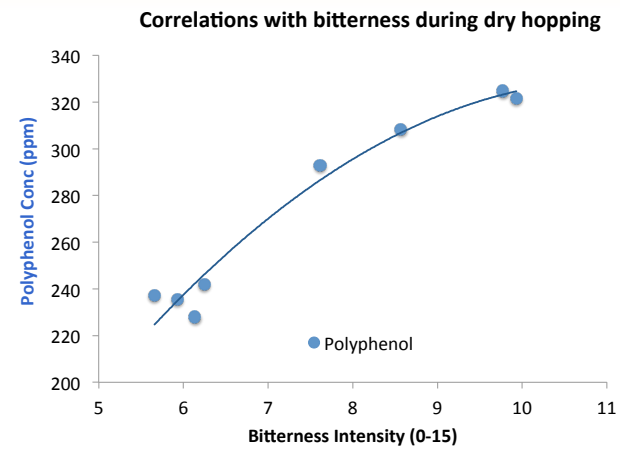
## Results - Linalool



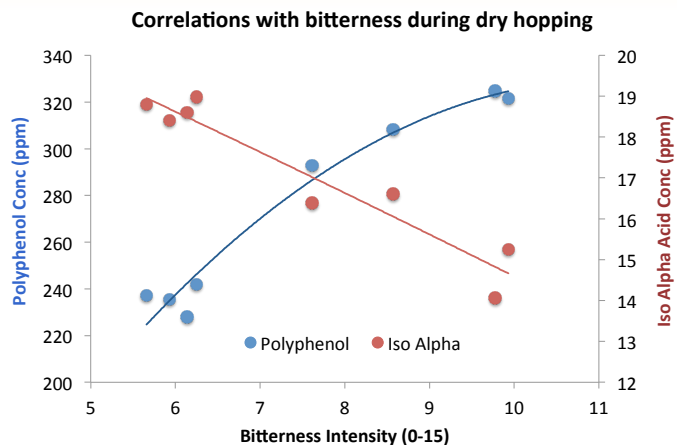
## Dry hopping study with Cascade pellets



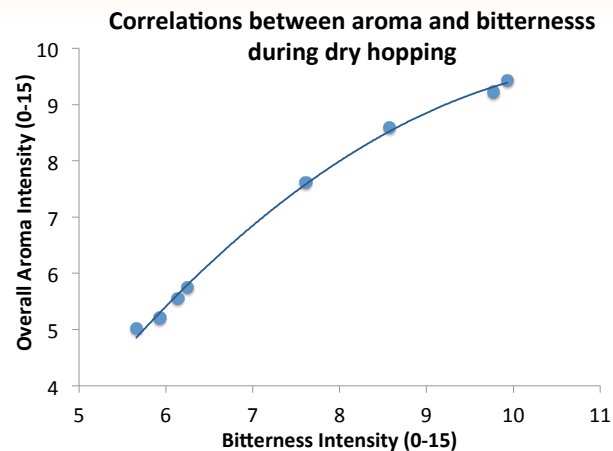
## Dry hopping study with Cascade pellets



## 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

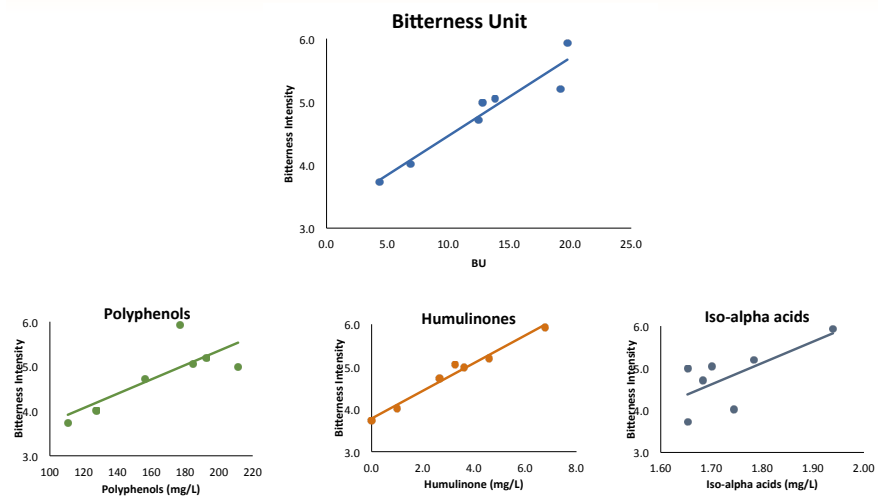
### Sensory protocol

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

### Instrumental analyses

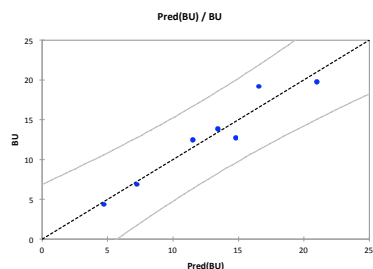
- Hop acids – HPLC
- Polyphenols
- Bitterness Units

## Contributions to bitterness intensity

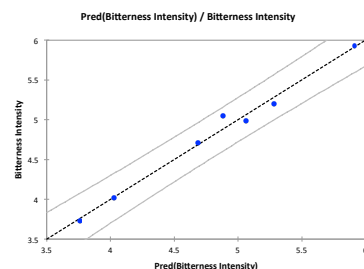




## Contributing factors to dry hop bitterness



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



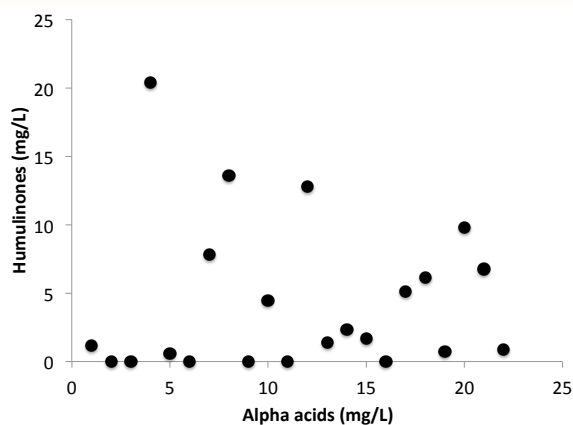
$$\begin{aligned} \text{Bitterness Intensity} = & 5.5 \\ & - 1.0 \times [\text{IAA}] \\ & + 0.4 \times [\text{Humulinones}] \end{aligned}$$

## 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