

BREWERS

CONGRESS 2017

Robert Percival

Lallemand

Phil Lowry

Simply Hops



YEAST & HOP INTERACTIONS

BREWERS

CONGRESS 2017

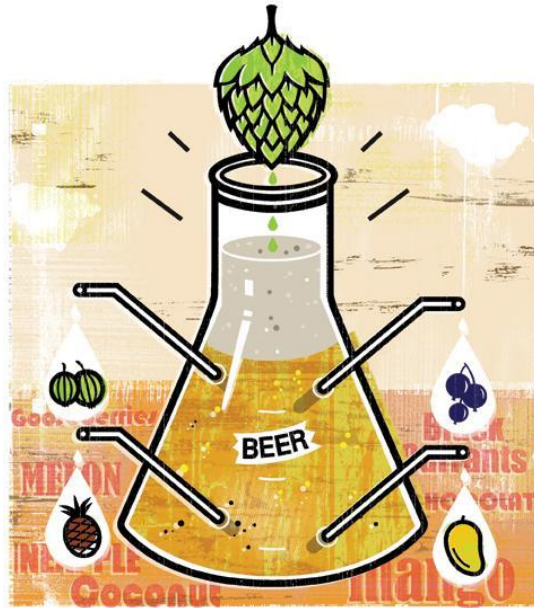
Hey cells.. Do you wanna
biotransform with me?



Modern Beer Styles

BREWERS
CONGRESS 2017

- Emphasis on hops



Draft Mag,
The Secret to hoppiness,
May 2013

Hop Composition

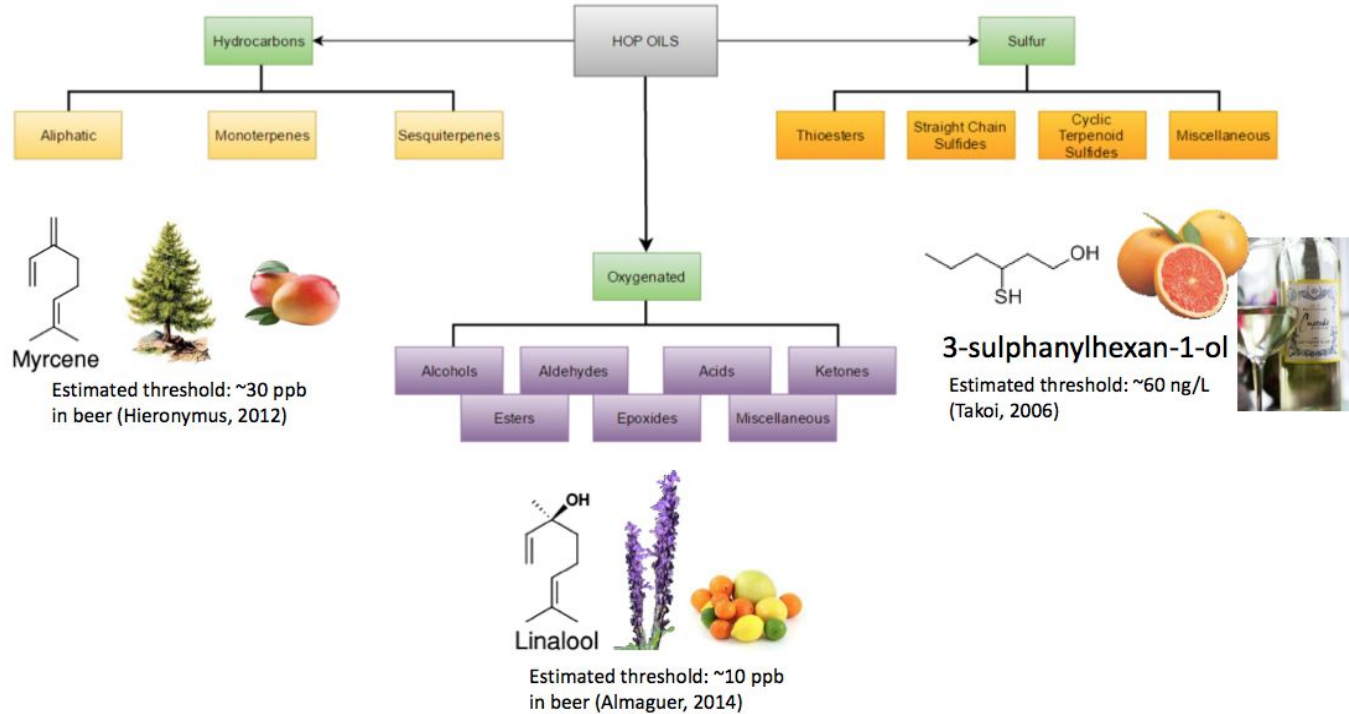
- POLYPHENOLS
- RESINS
- **ESSENTIAL OILS**

Hop Composition

- ESSENTIAL OILS

- Hydrocarbon fraction (50-80%)
 - Myrcene, Caryophellene, Farnesene, Humulene, ...
- Oxygenated fraction (20-50%)
 - Linalool, Geraniol, Nerol, ...
- Sulphur fraction (<1%)

Hop Oil Fractions



Hop Oils – Hydrocarbon fraction



- **Myrcene**

- The largest of the hop oils
- Up to 40-60% of the hop oil, though most noble hops are low in myrcene (Saaz: 5-13%).
- 64°C boil point, hence volatilize when you boil it
- **Herbal** notes, described as green, balsamic, hoppy in small quantities
- Slight **piney/resinous** flavor

<http://beersmith.com/blog/2013/01/21/late-hop-additions-and-hop-oils-in-beer-brewing/>

Hop Oils – Hydrocarbon fraction

BREWERS
CONGRESS 2017



- **Farnesene**

- Found in the coating of apples and other fruits
- Provides the "**green apple**" flavor as well as **flowery, citrusy, woody** and at the extreme end musty, woody or vegetative.
- Smallest of the hop oils (typically less than 1%)
- Oxidizes rapidly, therefore it is best preserved as a late or post boil hop addition

<http://beersmith.com/blog/2013/01/21/late-hop-additions-and-hop-oils-in-beer-brewing/>

Hop Oils – Oxygenated fraction



- **Linalool**

- Used as an indicator substance (indicator of hoppy beer)
- **Floral, spicy, lavender-like, sweet and citrus-like** aroma (orange)
- Closely related to myrcene (also used in perfume industries)
- Found naturally in numerous flower and spice plants

<http://beersmith.com/blog/2013/01/21/late-hop-additions-and-hop-oils-in-beer-brewing/>

Hop Oils – Oxygenated fraction

- **Geraniol**
 - Floral, rose-like, geranium flavor
 - Also used in perfume industries



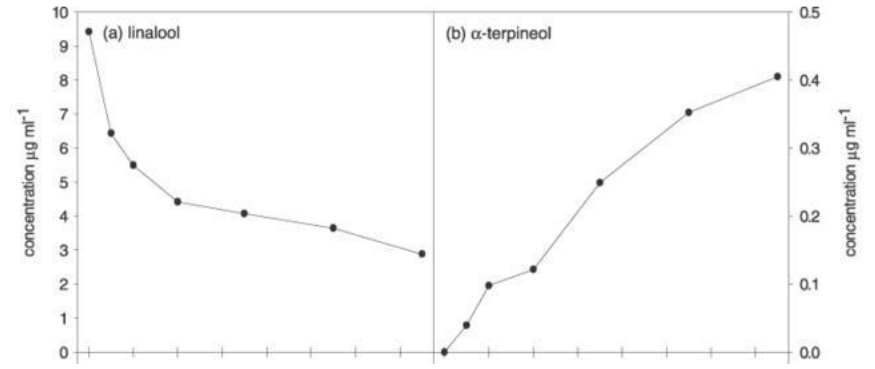
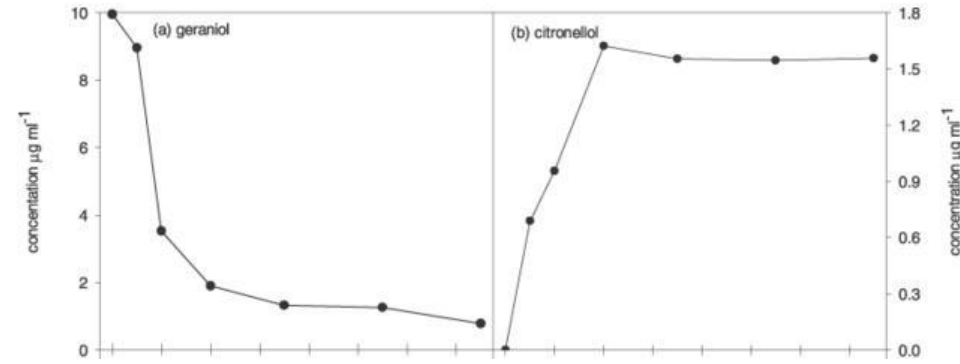
Biotransformation

- **Modification made to substance by an organism**
 - Geraniol converted into citronellol
 - Linalool converted into terpineol

- **Biotransformation of hop compounds in beer can occur in two forms:**
 - When one compound is transformed into another
 - By the hydrolysis of a glycoside

<http://draftmag.com/hop-compound-biotransformation/>

Biotransformation



Biotransformation

- **Examples:**

- Carbonyls reduced to hydroxyls (Mielgard 1986)
- Ester hydrolysis and trans-esterification (Peacock 1981)
- Hop degradation products to fruity esters (Nielsen 2009)
- **Glycosidically bound aroma precursors are hydrolyzed**
(Kollmannsberger 2006)

Sharp, Daniel; Vollmer, Dan; Shellhammer, Thomas.
Understanding How to Control Flavor and Aroma Consistency in Dry Hopped Beer.
Presentation at the Craft Brewers Conference 2015 (Portland, OR)

Glycosides... What's that?

- Found in nature
- Sugar bound molecules
- Water-soluble
- Non-volatile
- Used for storage and transport in plants

Sharp, Daniel; Vollmer, Dan; Shellhammer, Thomas.
Understanding How to Control Flavor and Aroma Consistency in Dry Hopped Beer.
Presentation at the Craft Brewers Conference 2015 (Portland, OR)

Glycoside Hydrolysis

- **Certain yeast strains have are capable of transforming non-aromatic glycosides into aromatic terpenoids**
- **Biotransformation is promoted when yeast is active (e.g. Dry-hopping during last fermentation)**

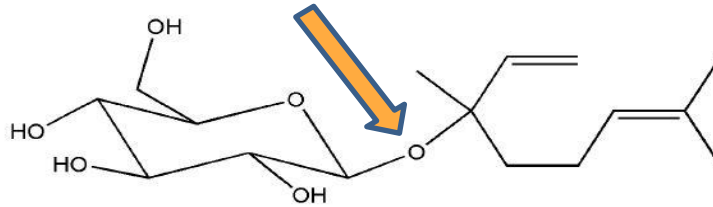
Sharp, Daniel; Vollmer, Dan; Shellhammer, Thomas.

Understanding How to Control Flavor and Aroma Consistency in Dry Hopped Beer.

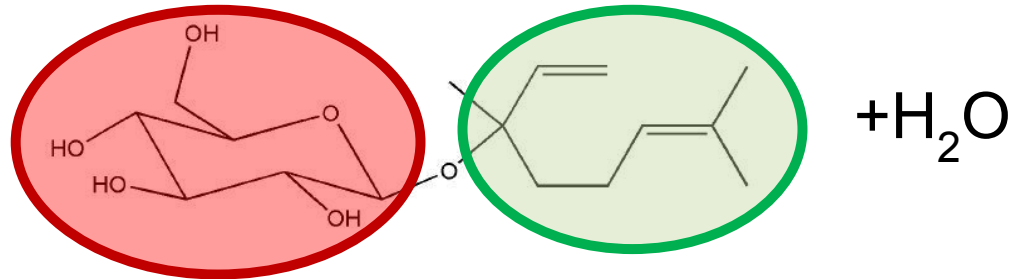
Presentation at the Craft Brewers Conference 2015 (Portland, OR)

Glycoside Hydrolysis

ENZYME (β -glycosidase)



LINALYL GLYCOSIDE (Non-aromatic)



CARBOHYDRATE (Glucose) HOP OIL (Linalool) AROMATIC

Yeast & Hop Interactions

- **Hop oils are lost during fermentation by:**
 - CO₂ stripping (highly volatile)
 - Masking (other present compounds)
 - Adsorption (yeast membrane)

Sharp, Daniel; Shellhammer, Thomas.

Recent Advances in Controlling Flavor and Aroma in Hoppy Beers.

Presentation at the Craft Brewers Conference 2016 (Philadelphia, PA)

Yeast & Hop Interactions

- **Dry-hopping (late fermentation)**
 - Right before reaching FG
 - Less CO₂ stripping
 - O₂ pickup from DH is minimized by active yeast
 - Biotransformation (yeast interaction)
 - Ethanol presence (higher solubility)
 - Still turbulent (mixing effect)

Sharp, Daniel;

Shellhammer, Thomas.

*Recent Advances in Controlling
Flavor and Aroma in Hoppy Beers.*

Presentation at the Craft Brewers
Conference 2016 (Philadelphia, PA)

What does it taste like?

| Enzymatic hydrolysis β -Glucosidase, pH 5, 24 h, 40 °C | Addition of enzyme | Without enzyme |
|---|-----------------------|-------------------|
| 3(Z)-Hexenol | 9 | 0 |
| 1-Octen-3-ol | 484 | 0 |
| 1,5-Octadien-3-ol | 39 | 0 |
| Linalool | 9 | 0 |
| α -Terpineol | 17 | 0 |
| 8-Hydroxy-linalool I | 6 | 0 |
| 8-Hydroxy-linalool II | 32 | 0 |
| Benzylalcohol | 82 | 15 |
| 3-Hydroxy-7,8-dihydro- β -ionol | 10 | 0 |

| | | |
|-------|---|--|
| Aroma | Mostly grapefruit and pine with some tropical pineapple, orange and caramel backin' it up | Mostly pine with some citrus, orange and grapefruit , followed by tropical pineapple aroma as well, slight caramel and isoamyl acetate |
|-------|---|--|

What does it taste like?

BREWERS
CONGRESS 2017



Possible combinations....

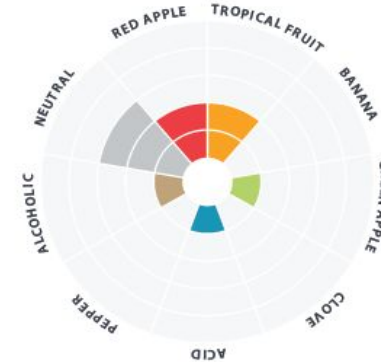
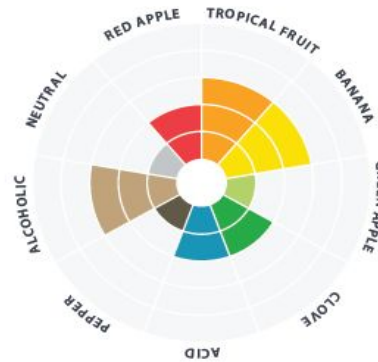
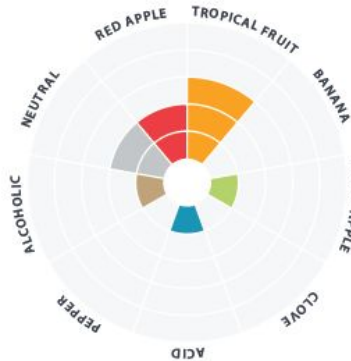


| | CITRA™ | Hersbrucker | EKG |
|---|--------|-------------|-----|
| LALLEMAND LalBrew New England AMERICAN EAST COAST ALE YEAST SACCHAROMYCES CEREVISIAE | X | Y | Z |
| LALLEMAND ABBAYE BELGIAN-STYLE ALE YEAST SACCHAROMYCES CEREVISIAE | Y | X | Y |
| LALLEMAND WINDSOR BRITISH STYLE BEER YEAST SACCHAROMYCES CEREVISIAE | Z | Y | X |

Aromatic yeasts

BREWERS

CONGRESS 2017



Conclusions

- Hop aroma and flavour is complex
- Yeast interaction with hop derived constituents can be significant
- Yeast strain selection can impact on aroma and flavour of beer
- Hop addition and timing is critical
- Scope for creativity and experimentation..... **Have fun!**

References

<http://beersmith.com/blog/2013/01/21/late-hop-additions-and-hop-oils-in-beer-brewing/>

<https://byo.com/stories/issue/item/3187-advanced-dry-hopping-techniques>

<https://beersensoryscience.wordpress.com/2010/11/30/glycosides/>

<http://draftmag.com/hop-compound-biotransformation/>

- A Study of Factors Affecting the Extraction of Flavor When Dry Hopping Beer.* Wolf, P. (MSc Thesis)
- Sharp, Daniel; Vollmer, Dan; Shellhammer, Thomas. *Understanding How to Control Flavor and Aroma Consistency in Dry Hopped Beer.* Presentation at the Craft Brewers Conference 2015 (Portland, OR)
- Sharp, Daniel; Shellhammer, Thomas. *Recent Advances in Controlling Flavor and Aroma in Hoppy Beers.* Presentation at the Craft Brewers Conference 2016 (Philadelphia, PA)
- King, Andrew; Dickinson, Richard. (2003). *Biotransformation of hop aroma terpenoids by ale and lager yeasts.* Retrieved from <http://onlinelibrary.wiley.com/doi/10.1111/j.1567-1364.2003.tb00138.x/full>