

# Hop Flavor

Beyond Aroma & Bitterness

# Sensory Examination of Beer

- Outcomes differ for each individual based on their particular sensitivities
- Despite these sensitivities many can agree on certain qualities of a particular product
  - Aroma (varying levels of complexity)
  - Flavor (pleasant vs. harsh)
  - Alcohol (high vs. low)
  - Bitterness (astringent vs. imperceptible)
  - Drinkability (one vs. several)
  - Aftertaste (lingering vs. pleasant)
- Popularity of certain brands results from a favorable consensus on the characteristics described above
- With few exceptions any flavor defects will negatively impact the brand

# Hops

- Our beer drinking experience is impacted by the hops selected for a particular brew
  - Bittering vs. noble
  - Single varietal vs. a combination of varieties
  - Pellets vs. extract
  - Some combination thereof
- Components of hop flavor
  - Aroma derived from hop oils
  - Bitterness derived from resins
- Common brewing practice
  - Add hops early in the boil to impart [bitterness](#)
  - Add hops late to the boil or whirlpool for [aroma](#)

# Hop Extraction Processes

- Hops can be extracted in a number of ways
  - Boiling wort in the brew kettle
  - Using liquid or super-critical CO<sub>2</sub>
- CO<sub>2</sub> extracts the hydrophobic portion of hops which includes the oils and resins
- What remains is the water-soluble portion (20-25% of the original weight)
  - Carbohydrates
  - Proteins
  - Polyphenols
  - Inorganic material
- Could the remains of the CO<sub>2</sub> extraction process potentially contribute to the flavor of beer?

# Miller's Challenge

- Hopping regime for Miller's flagship brand created a challenge
  - Miller High Life's signature package – a clear glass bottle
  - Company had to address the resulting skunky character that developed in Miller High Life
  - Resulted in the development of a “reduced hop extract” resistant to the UV degradation processes leading to light-struck/skunky flavors
- Solve one problem, create another?
- Sensory evaluation revealed a subtle difference between conventionally hopped and extract hopped versions of Miller High Life
- Miller High Life hopped with extracts characterized as “good” but different?

# Understand the Flavor Difference

- Challenge for Miller's R&D group - understand the contribution of each of the components of the hops being extracted and their contribution to hop flavor
  - Soft resins
    - Alpha acids
    - Beta acids
  - Hops oils
  - Lipids
  - Waxes
  - Spent hop powder
- GOAL: move the sensory needle beyond "good"

# Missing Flavor Element

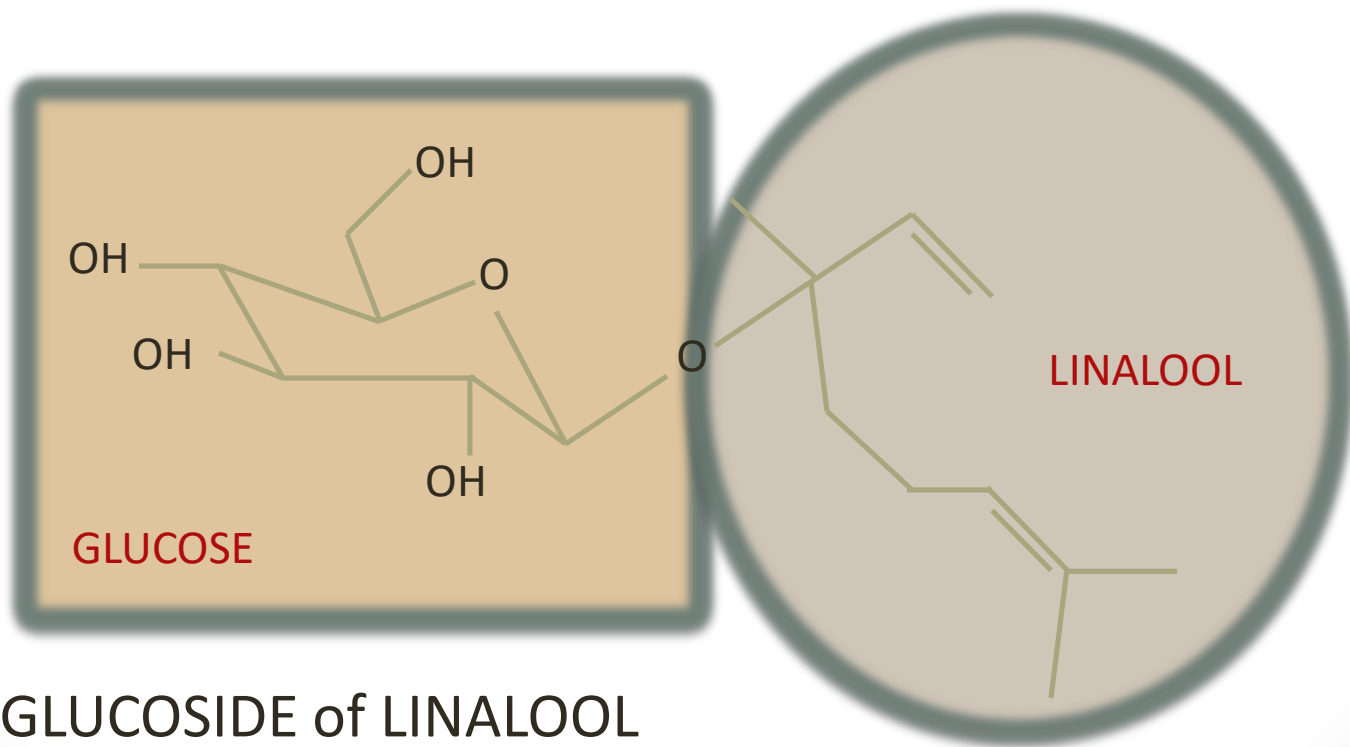
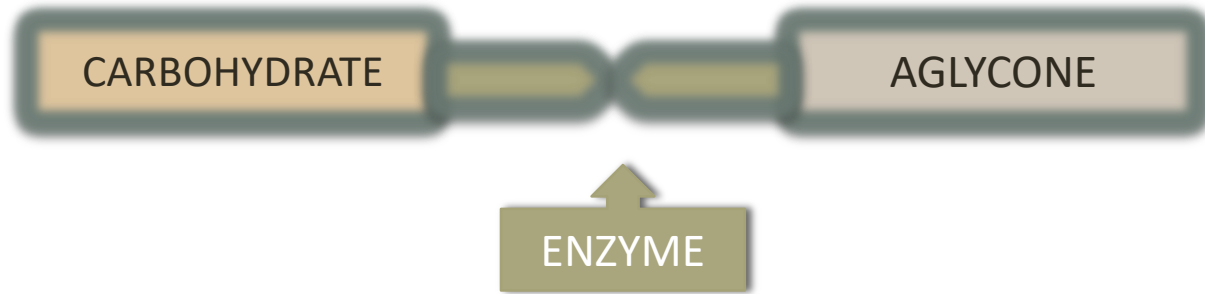
- Research focused on hop solids remaining after CO<sub>2</sub> extraction process
- Composition
  - Carbohydrates
  - Proteins
  - Polyphenols
  - Inorganic material
- Analysis of the carbohydrate portion of the spent hop material revealed the presence of glycosides
  - Carbohydrate (glucose specifically)
  - Aglycone

# Aglycones

- A class of compounds
- Found in hops, grapes, spices, fruits, plant flowers
- Flavorless while bound to the carbohydrate
- Not water-soluble in their free state
- Water soluble when bound to glucose
- Released by
  - Acid hydrolysis
  - Enzymatic catalysis
- Can be detected by the nose or tongue if unbound



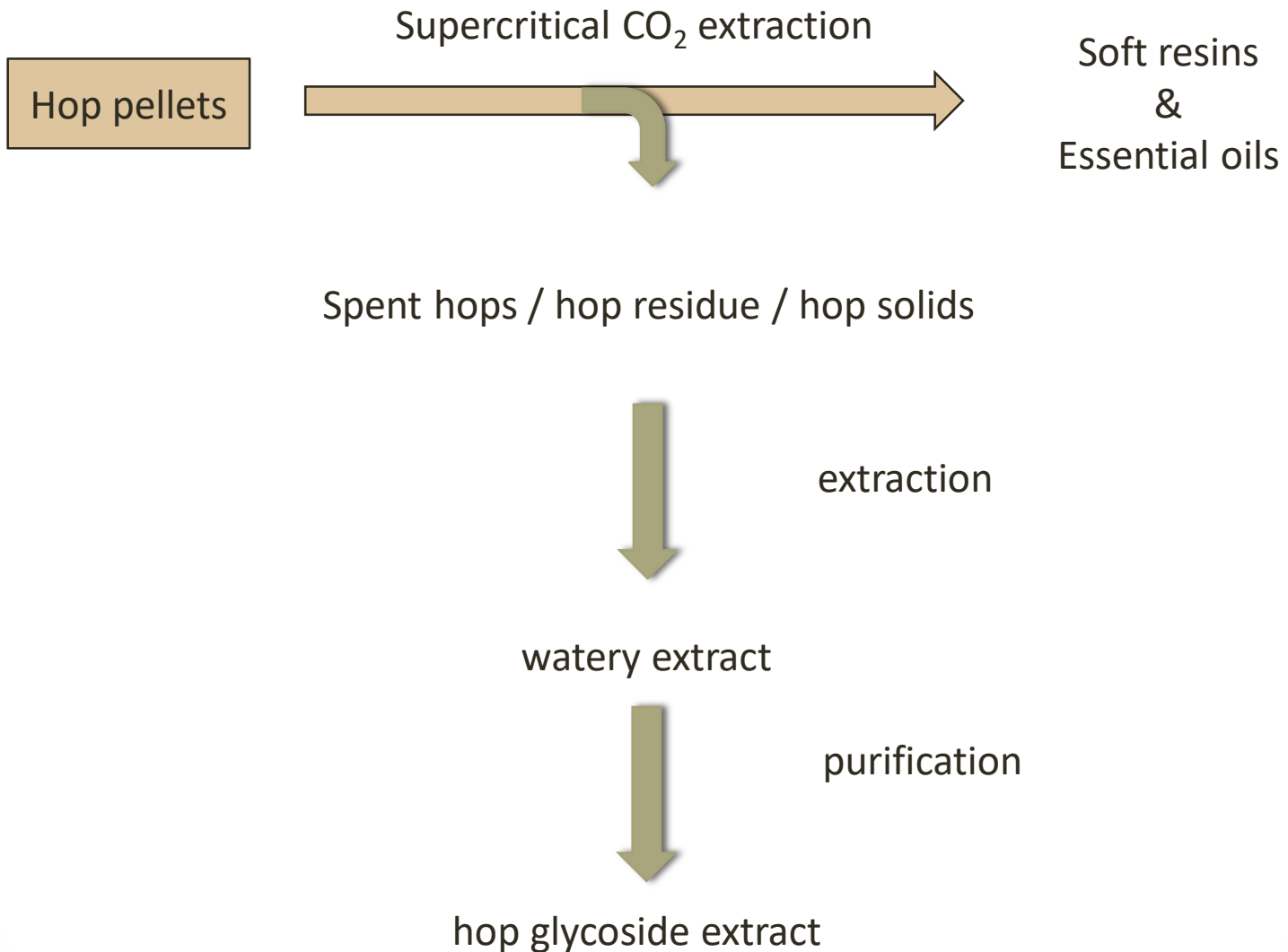
# Enzymatic Release of Aglycone



# Enzymatic Release of Aglycones

- Requires an enzyme specific to the glucosidic linkage – beta glucosidase
- Beta glucosidase occurs naturally
  - Plants
  - Bacteria
  - Fungi (yeasts)
    - Limited number of yeast strains
    - No commercially available strains of *S. Saccharomyces*
    - *Brettanomyces* (*B. custersii*)

# Isolation of Hop Glycosides



# Missing Flavor Element

Analysis of purified hop glycoside extract treated with beta glucosidase revealed a number of aroma & flavor compounds

Compound	Odorant/Flavorant
Benzaldehyde	Almond, maraschino cherry
Vanilla	Vanilla
Raspberry ketone	Raspberry
Geraniol	Floral, rose
Linalool	Floral
Phenylacetaldehyde	Honey, floral
Others	Primary alcohols, ketones, esters & aldehydes

# Missing Flavor Element

- Spent hops treated with beta glucosidase produced a hop aroma extract
- Sensory analysis results of extract hopped beer with hop aroma extract
  - Improved the overall liking as compared to the control (extract hopped beer with no hop aroma extract)
  - Produced a beer similar to conventional hopped product
- Conclusion

Kettle-hopped beer flavor can be achieved  
using hop aroma extract

# Future Considerations

- What we know
  - Glycosides have the ability to improve the flavor and aroma of beer
  - Certain strains of *Brettanomyces* have exo-cellular beta glucosidase activity
  - Commercially available strains of *S. saccharomyces* don't release beta glucosidase during fermentation
- What's next
  - Enhanced product characteristics when beta glucosidase present during fermentation
    - Improved dry hop character
    - Enhanced fruit flavors and aromas
  - Development of strains of *S. saccharomyces* with exo-cellular beta glucosidase activity

Thank you  
For  
your attention