

CRAFT
BREWERS
CONFERENCE®
& BrewExpo America

Exploring Hop Picking Windows and Their Impact on Flavor and Aroma



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OVERVIEW

- HOW WE GOT HERE – FINDING THE EDGE
- IN-FIELD SENSORY BY HOP GROWERS
- EL DORADO HOP & BEER COMPARISON
- CASCADE HOP & BEER COMPARISON
- HOP CREEP
- TAKEAWAYS



FINDING THE EDGE



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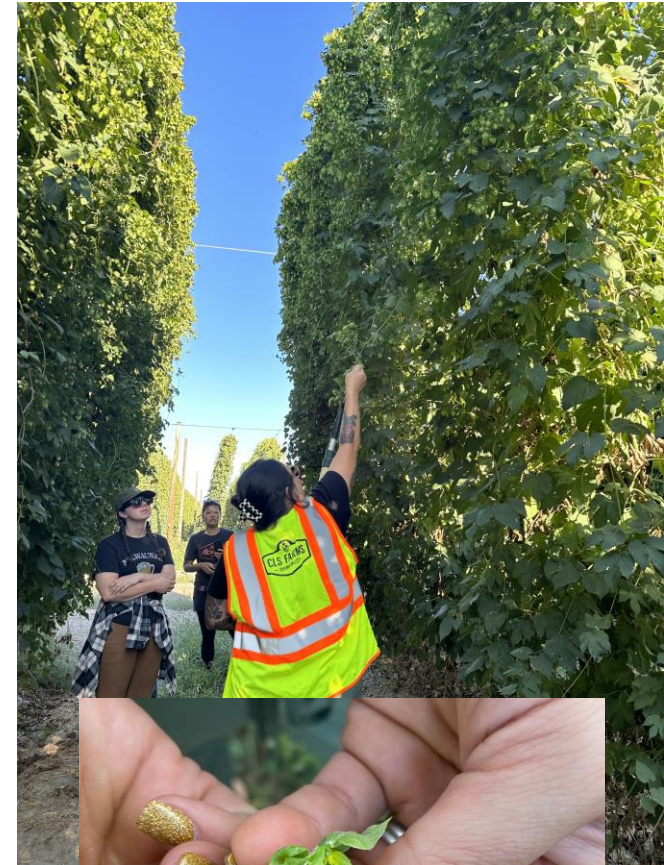
BREWER-GROWER RELATIONSHIP

- Feedback loop on hop picking windows – Finding the Edge
- Fixed vs. Dynamic picking dates
- Traditional methods
 - Dry matter
 - Date windows
 - 2023 Centennial
- Integration of art and science
- Exploring intra-varietal differences, not just variety vs. variety



CLS FARMS IN-FIELD SENSORY

- Consists of multiple people
- Decision Matrix
 - Training Dates
 - Location, soil types
 - **Plant material, virus vs. virus-free**
 - Field maturity, age, babies
 - Physical indicators
- Velocity of maturity, dominant aromas
- Open Mind → off aromas vs. targeted
- Quick assessment for decisions
- HopTechnic Harvest Readiness program for 2023



HOP SENSORY

Sample
Ox 



JOIN CODE: 8ANZ7



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EARLY, MID, LATE- HARVESTED EL DORADO

HOP & BEER ANALYSIS



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SENSORY



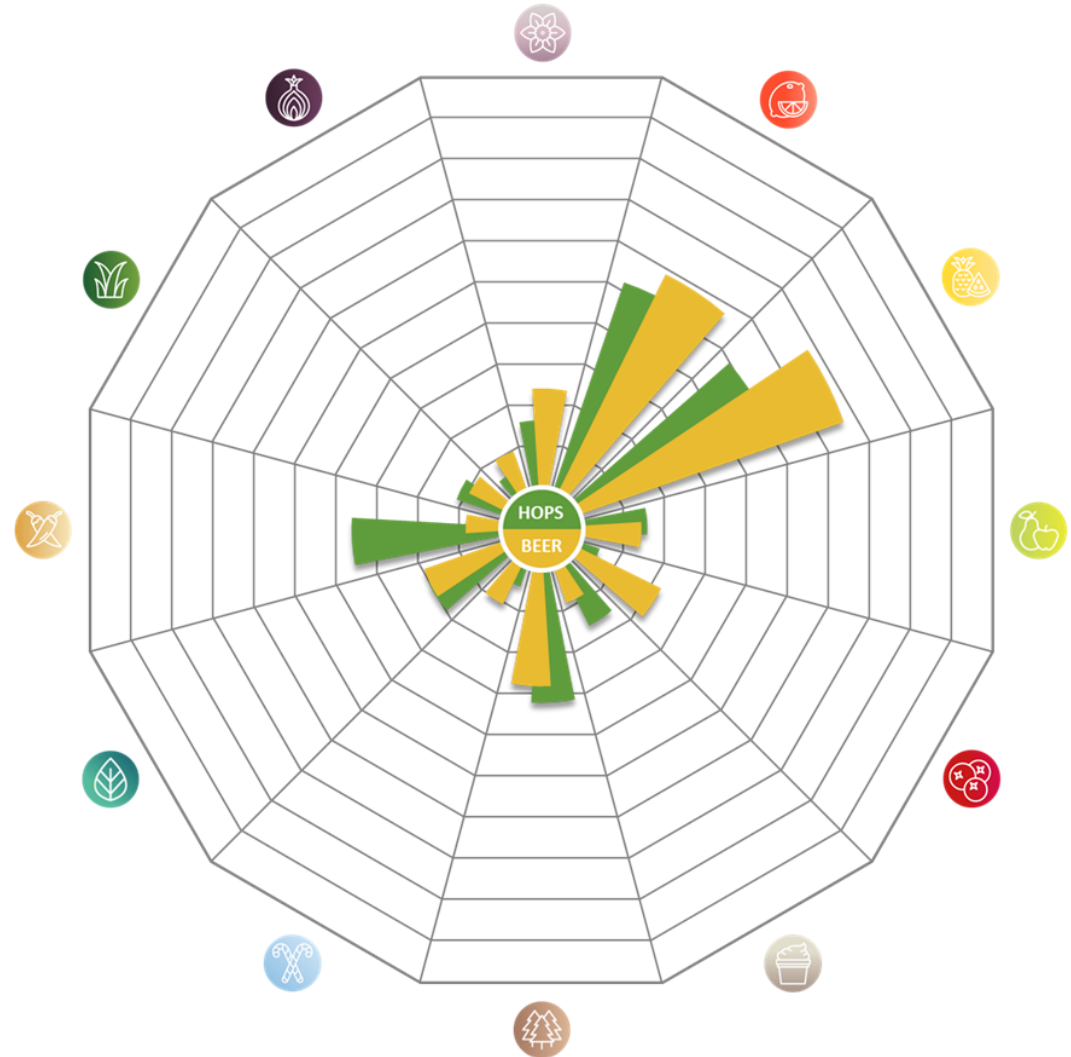
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EARLY HARVEST – EL DORADO®

Early Maturity

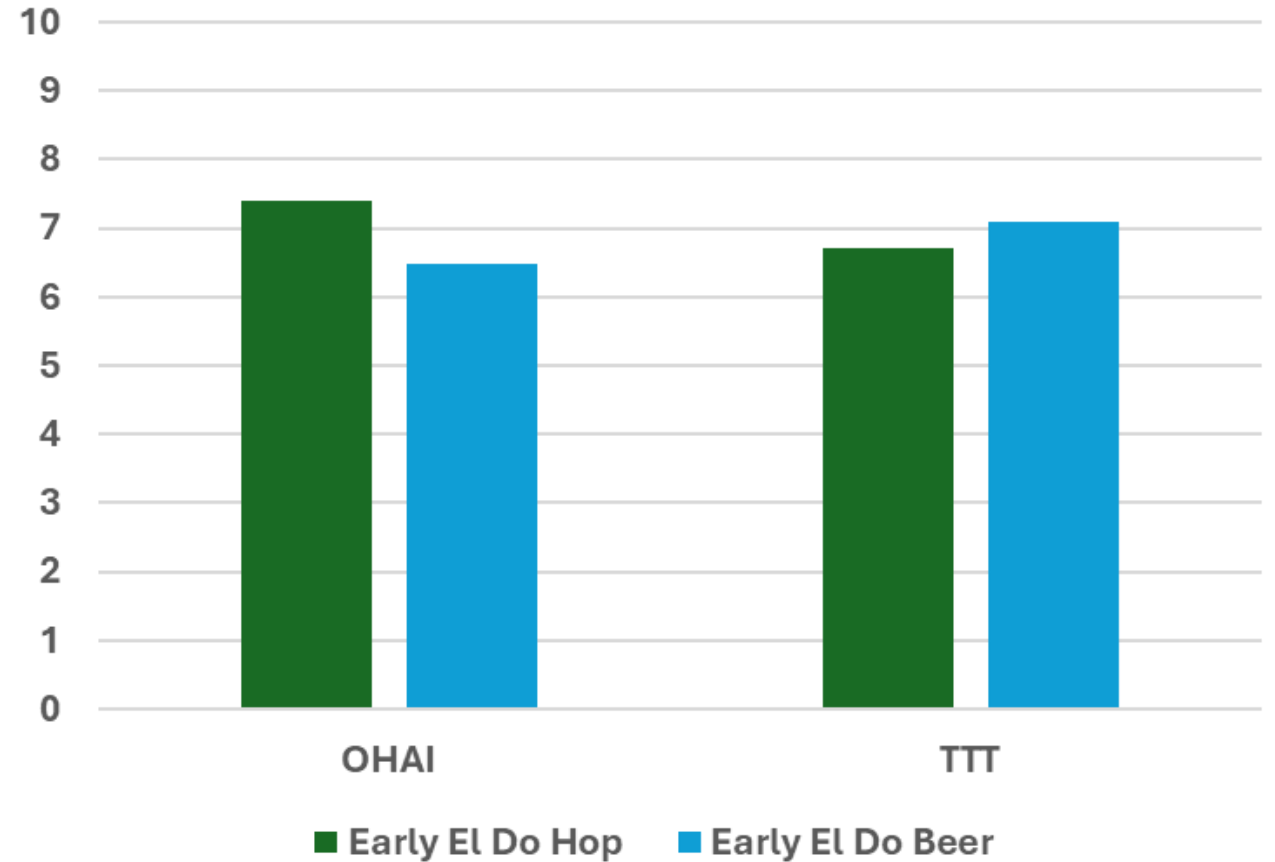
Aroma notes: citrusy, brighter

- Lot 23-WA405-040
- Harvest Date: 9/18
- Bright, Clean Citrus notes, especially of Lemon and Orange, and Green Fruits like Pear
- Lower intensity



EARLY HARVEST – EL DORADO®

| Attributes | Early El Do Hop | Attributes | Early El Do Beer |
|-----------------------|-----------------|-----------------------|------------------|
| Orange | 40% | Orange | 43% |
| Chile Pepper | 33% | Lemon | 36% |
| Lime | 27% | Pineapple | 36% |
| Resin | 27% | Grapefruit | 29% |
| Generic Herbal | 27% | Pear | 29% |
| Grapefruit | 20% | Generic Floral | 21% |
| Tangerine | 20% | Lime | 21% |
| Peach | 20% | Tangerine | 21% |
| Pineapple | 20% | Peach | 21% |
| Pine | 20% | Apricot | 21% |
| | | Mango | 21% |
| | | Passion Fruit | 21% |
| | | Dried Fruit | 21% |
| | | Blackberry | 21% |
| | | Pine | 21% |
| | | Generic Woody | 21% |
| | | Basil | 21% |
| | | Generic Herbal | 21% |
| | | Hay | 21% |



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MID HARVEST – EL DORADO®

Middle Maturity

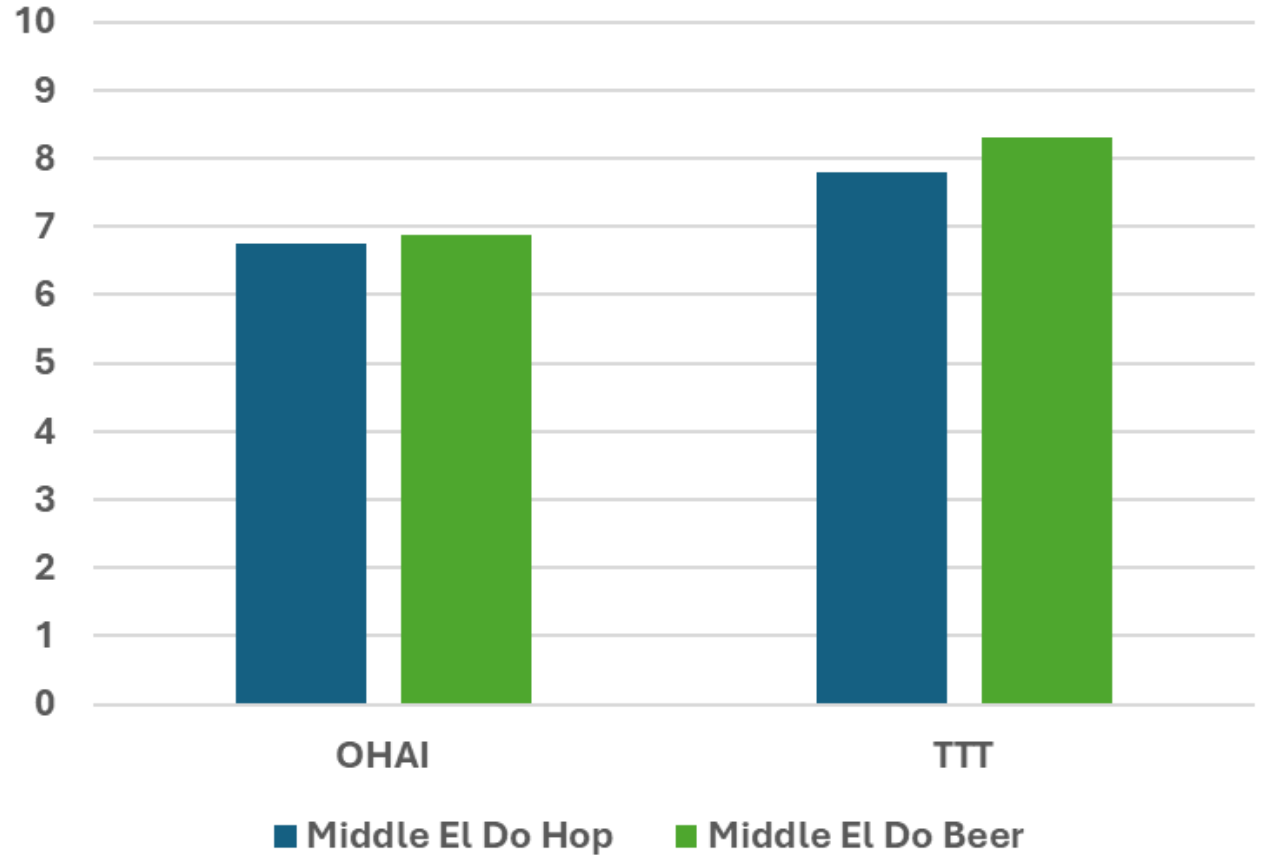
Aroma notes: melon/watermelon, pear

- Lot 23-WA405-063
- Harvest Date: 9/23
- Complex Citrus notes, a mixture of Lemon, Orange, and Grapefruit, Moderate Sweet Fruit with notes of Pineapple and Melon, and slight Green Fruit like Pear. Slight floral like Roses.
- Moderate intensity



MID HARVEST – EL DORADO®

| Attributes | Middle El Do Hop | Attributes | Middle El Do Beer |
|-------------------------|------------------|-------------------------|-------------------|
| Lemon | 33% | Orange | 50% |
| Orange | 27% | Tangerine | 36% |
| Lime | 20% | Pineapple | 36% |
| Passion Fruit | 20% | Generic Berry | 36% |
| Generic Sweet Fruit | 20% | Generic Floral | 29% |
| Apple | 20% | Peach | 29% |
| White Wine Grape | 20% | Mango | 29% |
| Resin | 20% | Honeydew | 29% |
| Wintergreen | 20% | Pine | 29% |
| Chile Pepper | 20% | Generic Citrus | 21% |
| | | Passion Fruit | 21% |
| | | Melon | 21% |
| | | Pear | 21% |
| | | White Wine Grape | 21% |
| | | Strawberry | 21% |
| | | Generic Woody | 21% |
| | | Generic Herbal | 21% |
| | | Carnation | 14% |



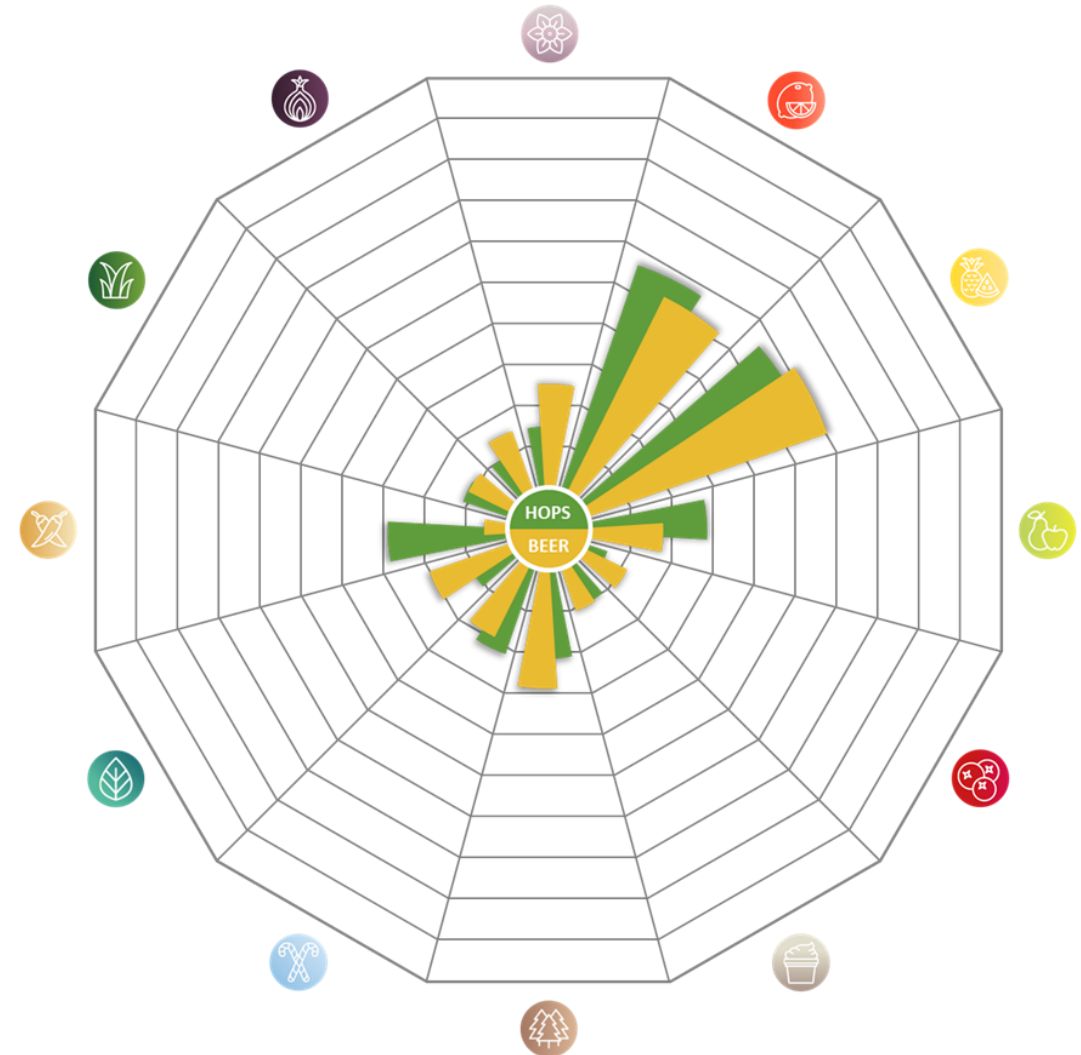
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LATE HARVEST – EL DORADO®

Peak Maturity

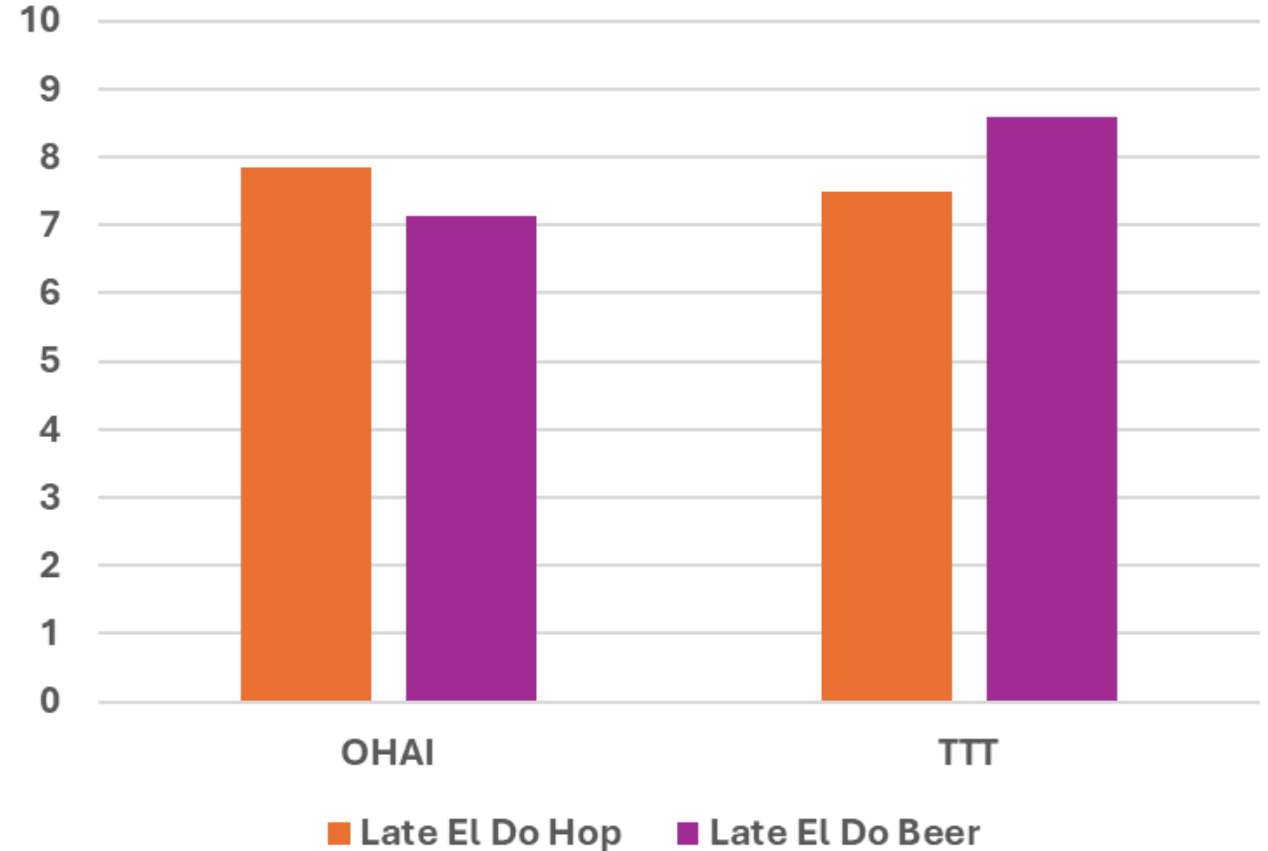
Aroma notes: stone fruit, tropical, hard candy, deeper aromas

- Lot 23-WA405-072
- Harvest Date: 9/27
- Overall, richer and more complex aromas: Lemon and Orange, Mixed Sweet Fruit with Lychee, Stone Fruits (like Apricot), Tropical and Watermelon Candy (think Jolly Ranchers and Laffy Taffy). The Complex fruits are complemented with notes of Pine Resin and Menthol. Floral, Roses. Clean.
- Highest intensity



LATE HARVEST – EL DORADO®

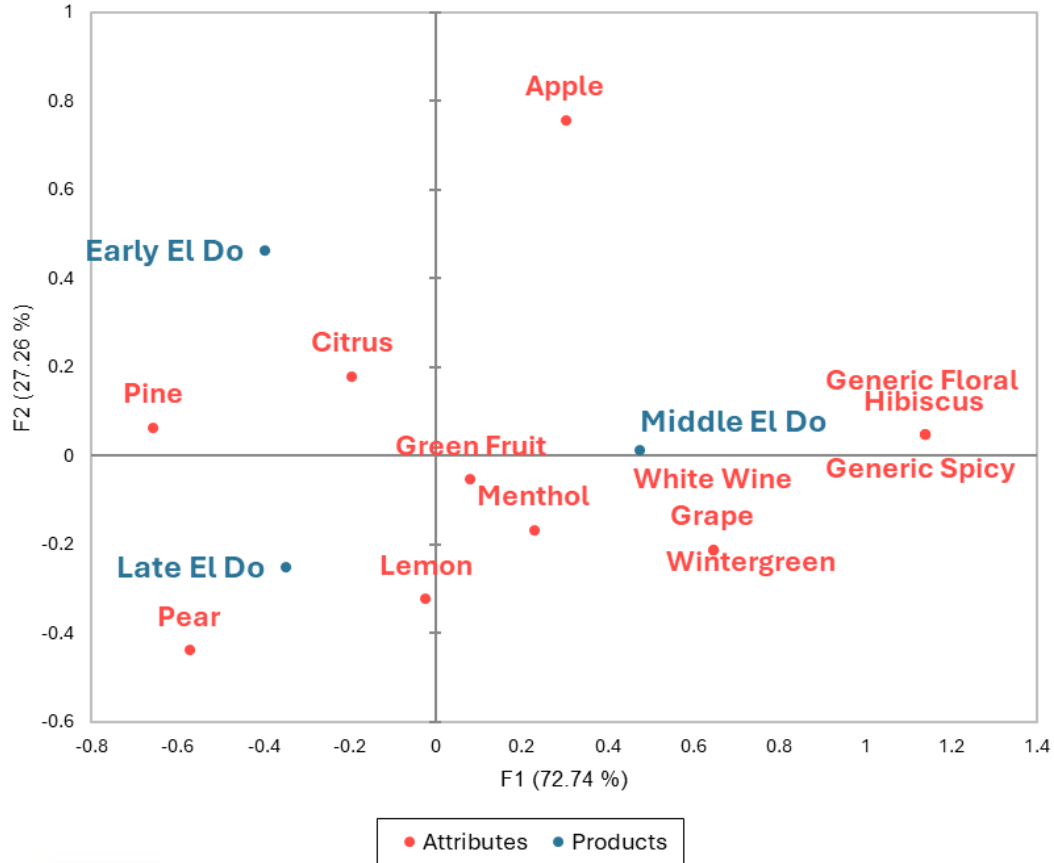
| Attributes | Late El Do Hop | Attributes | Late El Do Beer |
|---------------------|----------------|------------------|-----------------|
| Lemon | 40% | Orange | 50% |
| Pear | 33% | Grapefruit | 36% |
| Pine | 33% | Lemon | 36% |
| Orange | 27% | Peach | 36% |
| Generic Sweet Fruit | 27% | Apricot | 36% |
| Grapefruit | 20% | Mango | 36% |
| Tangerine | 20% | Pineapple | 36% |
| Peach | 20% | Melon | 36% |
| Cherry | 20% | Pear | 29% |
| | | Apple | 29% |
| | | Generic Vegetal | 29% |
| | | Generic Floral | 21% |
| | | Tangerine | 21% |
| | | White Wine Grape | 21% |
| | | Honey | 21% |
| | | Pine | 21% |
| | | Jasmine | 14% |



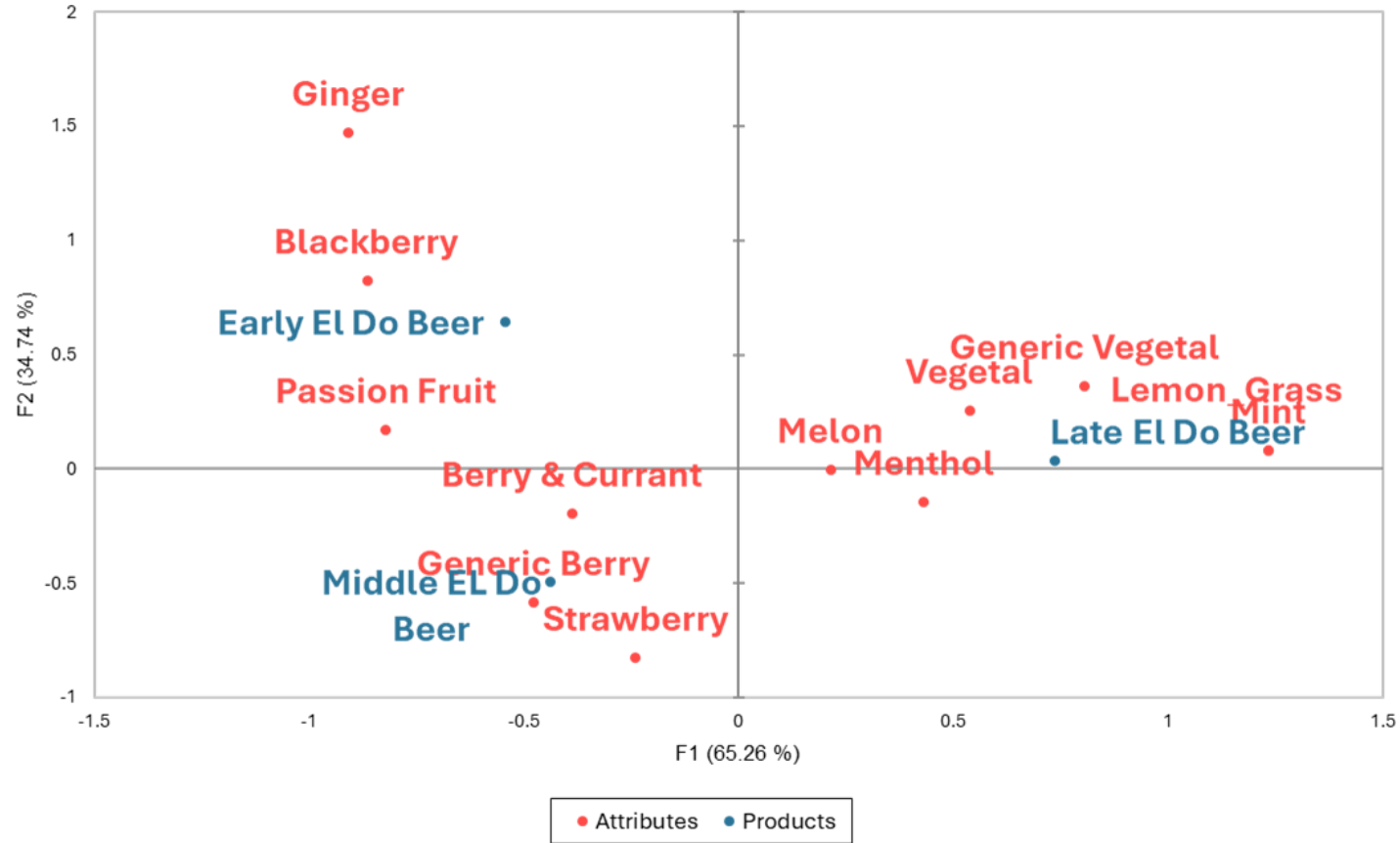
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MAPPING THE DIFFERENCES

Hop Correspondence Analysis (CATA)



Beer Coorespondence Analysis (CATA)



CHEMISTRY ANALYSIS



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TERPENE CHEMISTRY - HOPS

| Crop year | Variety | Harvest Point | GCMS Corrected Responses | | |
|-----------|-----------|---------------|--------------------------|--------------------|---------------------|
| | | | Linalool | Geraniol | Citral |
| 2023 | El Dorado | Early | 2.87 | 0.10 | 0.08 |
| 2023 | El Dorado | Middle | 2.40 | 0.14 | 0.11 |
| 2023 | El Dorado | Late | 4.08 | 0.19 | 0.23 |
| | | | | | |
| | | | | | |
| Crop year | Variety | Harvest Point | GCMS Corrected Responses | | |
| | | | Geranyl Acetate | Geranyl Propionate | Geranyl Isobutyrate |
| 2023 | El Dorado | Early | 17.24 | 8.14 | 19.25 |
| 2023 | El Dorado | Middle | 13.36 | 5.53 | 12.76 |
| 2023 | El Dorado | Late | 32.31 | 13.00 | 29.07 |



TERPENES – HOPS & BEER

- Terpene composition between the El Dorado® dry-hopped beers showed an **increase in β -pinene and geraniol** from early to late harvest timing. Levels of limonene, linalool, humulene and myrcene were relatively similar.

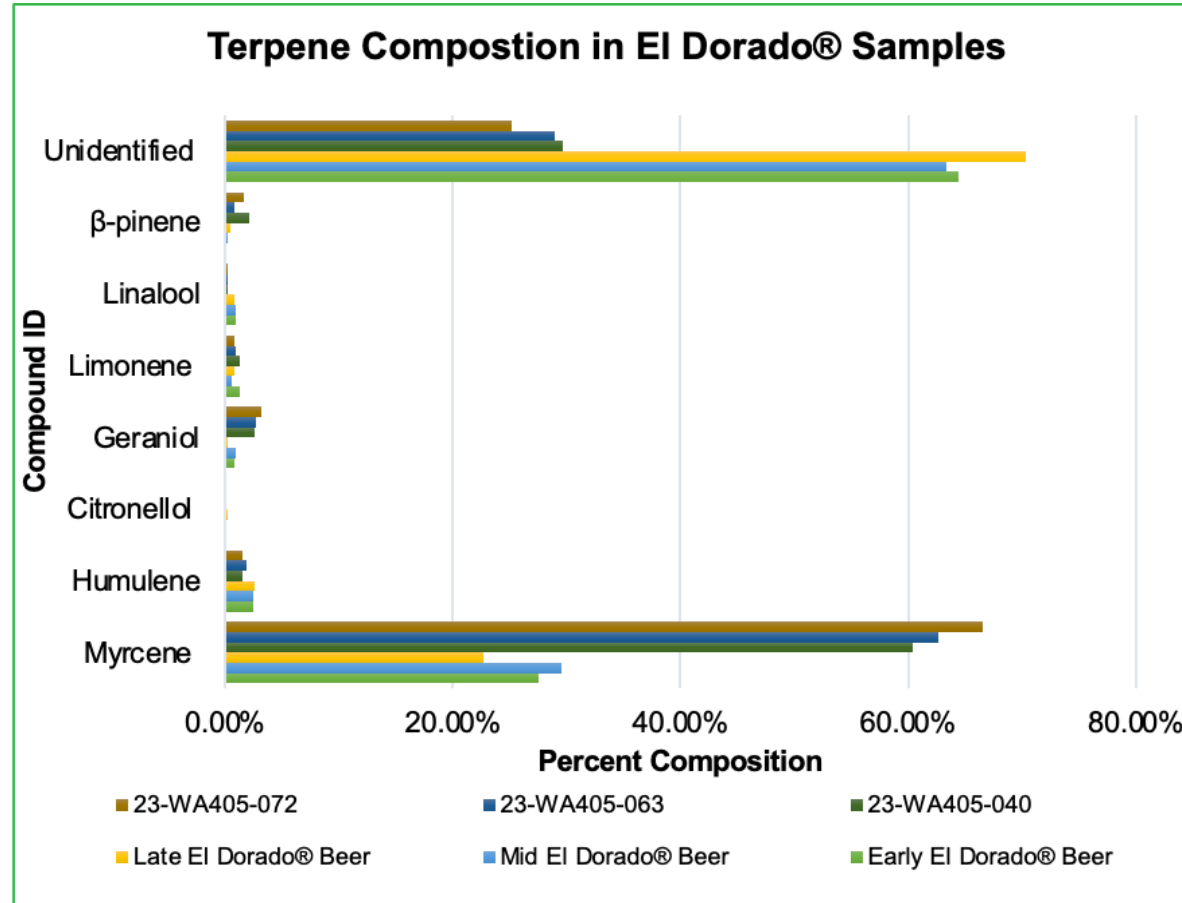


Figure 3. Percent composition of terpenes in El Dorado® beer and hop samples.

POLYFUNCTIONAL THIOLS - BEER

4SMP(4MMP)/MTI – 4-sulfanyl-4-methylpentan-2-one/methyl thioisovalerate: catty, black currant/ cheesy, fermented fruit

MTH – methyl thiohexanoate: guava, passionfruit, grapefruit

3SH (3MH) – 3-sulfanyhexan-1-ol: passionfruit, guava, tropical, grapefruit

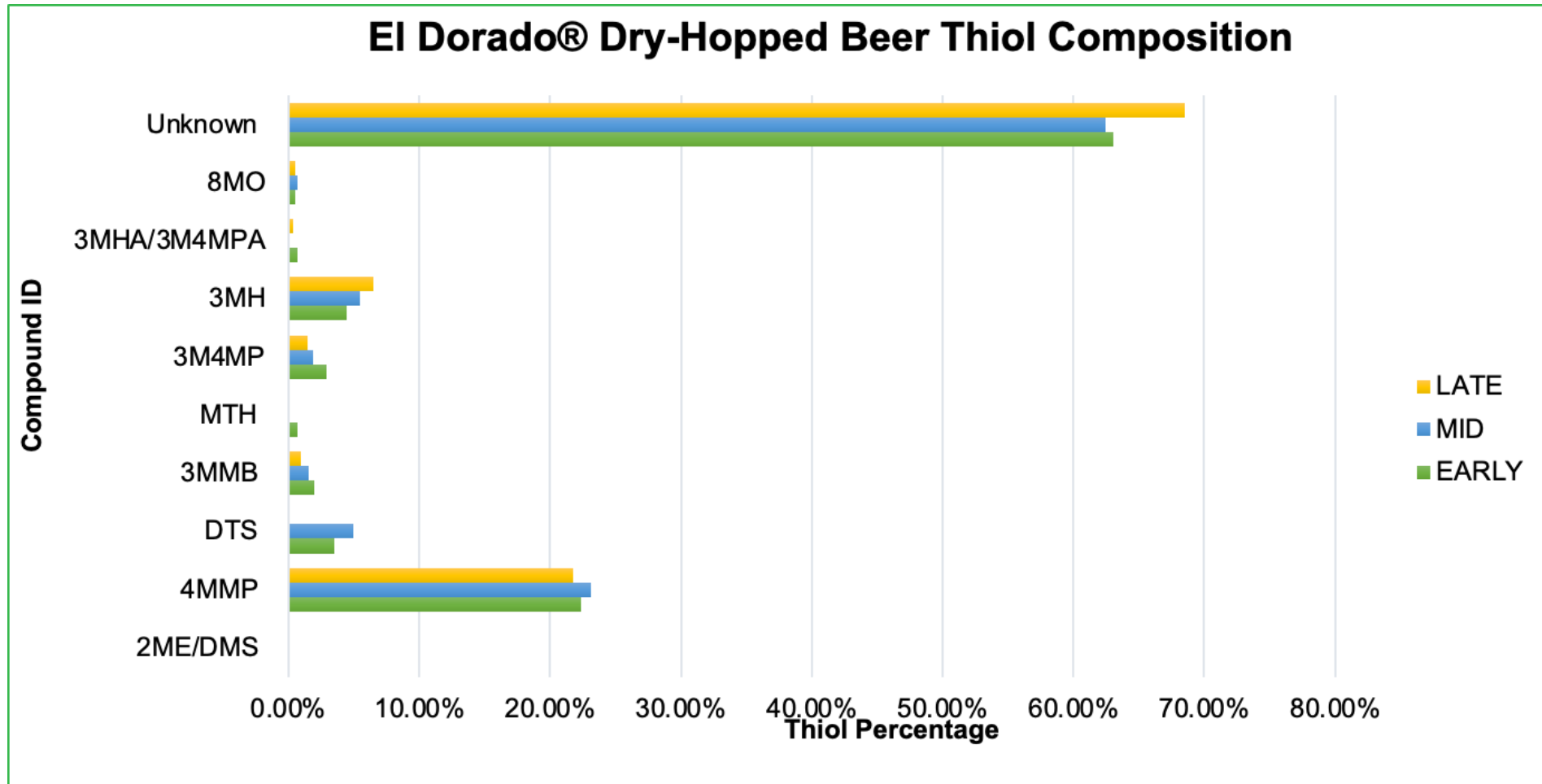
3SHA (3MHA) – 3-sulfanyhexyl acetate: passionfruit, black currant, tropical

- *Samples dry-hopped with El Dorado® samples showed **minor variations based on thiol composition.***

| Lot ID | DMS/2ME | 4MMP/MTI | DTS | 3M3MB | MTH | 3M4MP | 3MH | 3MHA/3M4MPA | 8MO | Unidentified |
|-----------------------|---------|----------|-------|-------|-------|-------|-------|-------------|-------|--------------|
| Early El Dorado® Beer | 0.00% | 22.36% | 3.97% | 1.96% | 0.00% | 2.89% | 4.42% | 0.67% | 0.54% | 63.05% |
| Mid El Dorado® Beer | 0.00% | 23.12% | 4.93% | 1.53% | 0.00% | 1.90% | 5.43% | 0.00% | 0.67% | 62.42% |
| Late El Dorado® Beer | 0.00% | 21.72% | 0.00% | 0.94% | 0.00% | 1.45% | 6.51% | 0.38% | 0.50% | 68.50% |



CONT. BEER



NORMAL VS. LATE- HARVEST CASCADE

HOP & BEER ANALYSIS



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SENSORY



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CASCADE

“NORMAL”

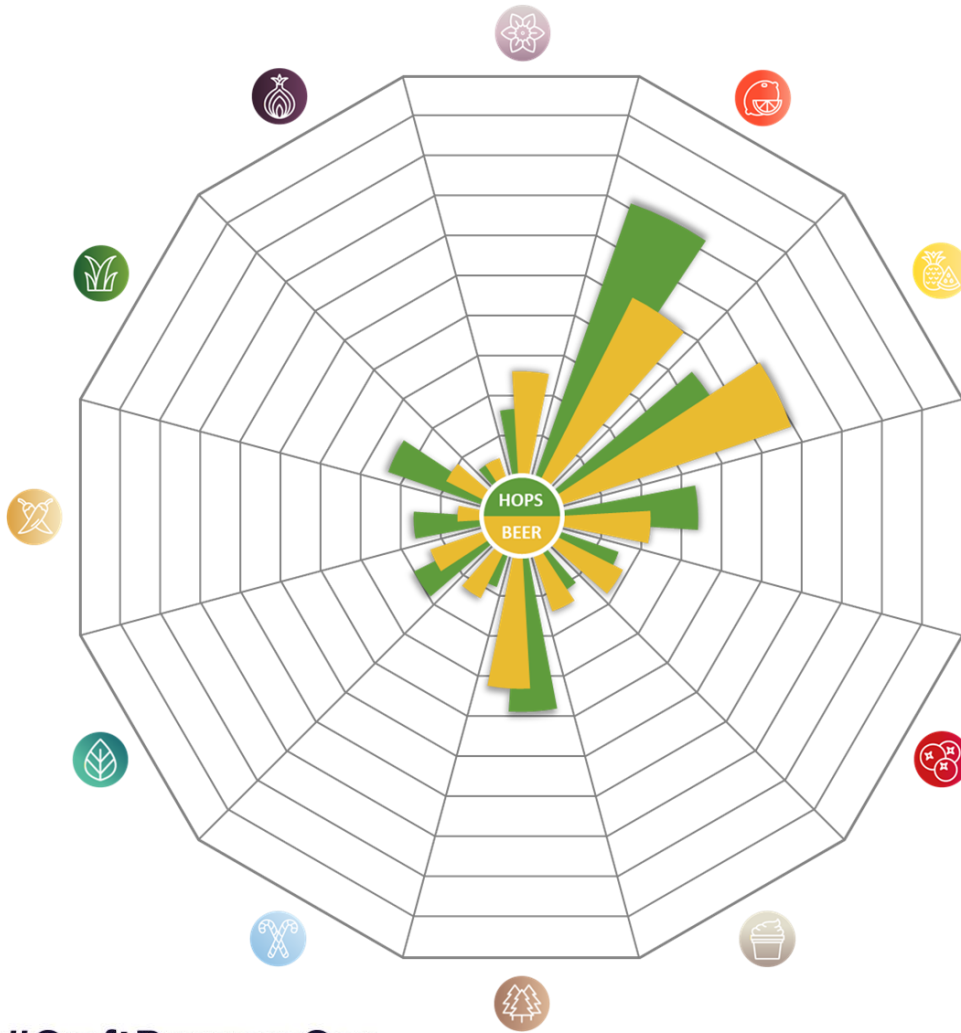
- Harvested: 09/07/2023
- Virus-Infected Plant Material
- Sensory descriptors: Pine, Floral, Citrus, Slight Herbal, Clean, No Dank

“LATE”

- Harvested: 10/6/2023
- Virus-Free Plant Material
- Sensory Descriptors: Tropical like Pineapple. Notes of Citrus like Orange. Slightly Woody and Cheesy. "Over the edge."



"NORMAL" vs. "LATE"



"NORMAL" vs. "LATE"

| Attributes | Normal Cascade Hop | Attributes | Normal Cascade Beer |
|-------------------|--------------------|---------------|---------------------|
| Orange | 33% | Orange | 50% |
| Lime | 33% | Lemon | 36% |
| Mango | 33% | Mango | 36% |
| Resin | 33% | Melon | 36% |
| Generic Floral | 27% | Pear | 36% |
| Grapefruit | 27% | Rose | 29% |
| Lemon | 27% | Resin | 29% |
| Pear | 20% | Lime | 21% |
| Apple | 20% | Peach | 21% |
| Pine | 20% | Apricot | 21% |
| Earthy | 20% | Generic Berry | 21% |
| Menthol | 20% | | |
| Black Pepper | 20% | | |
| Fresh Cut Grass | 20% | | |

| Attributes | Late Cascade Hop | Attributes | Late Cascade Beer |
|-------------------|------------------|---------------------|-------------------|
| Grapefruit | 33% | Lemon | 64% |
| Orange | 33% | Orange | 43% |
| Lemon | 33% | Resin | 36% |
| Ginger | 33% | Generic Floral | 29% |
| Pine | 27% | Mango | 29% |
| Earthy | 27% | Rose | 21% |
| Green Tea | 27% | Grapefruit | 21% |
| Pear | 20% | Lime | 21% |
| Generic Woody | 20% | Generic Citrus | 21% |
| Curry | 20% | Peach | 21% |
| Fresh Cut Grass | 20% | Apricot | 21% |
| Hay | 20% | Generic Sweet Fruit | 21% |
| Tangerine | 13% | Pear | 21% |
| | | White Wine Grape | 21% |
| | | Pine | 21% |



CHEMISTRY ANALYSIS



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POLYFUNCTIONAL THIOL CHEMISTRY - HOPS

4SMP(4MMP)/MTI – 4-sulfanyl-4-methylpentan-2-one/methyl thioisovalerate: catty, black currant/ cheesy, fermented fruit

MTH – methyl thiohexanoate: guava, passionfruit, grapefruit

3SH (3MH) – 3-sulfanylhexas-1-ol: passionfruit, guava, tropical, grapefruit

3SHA (3MHA) – 3-sulfanylhexyl acetate: passionfruit, black currant, tropical

| Lot ID | DMS/2ME | 4MMP/MTI | DTS | 3M3MB | MTH | 3M4MP | 3MH | 3MHA/ 3M4MPA | 8MO | Unidentified |
|---------------------------------|---------|----------|-------|-------|-------|-------|-------|-----------------|-------|--------------|
| 23-WA302-071 "Normal CAS" | 0.00% | 16.29% | 0.00% | 8.45% | 9.86% | 0.00% | 2.25% | 0.36% | 0.00% | 62.79% |
| 2023CAS- CLS-1 "Late CAS" | 0.00% | 7.82% | 0.00% | 0.00% | 0.48% | 0.00% | 4.90% | 0.35% | 0.45% | 86.01% |



Table 3. Percent of detected thiols in hop samples of Cascade.

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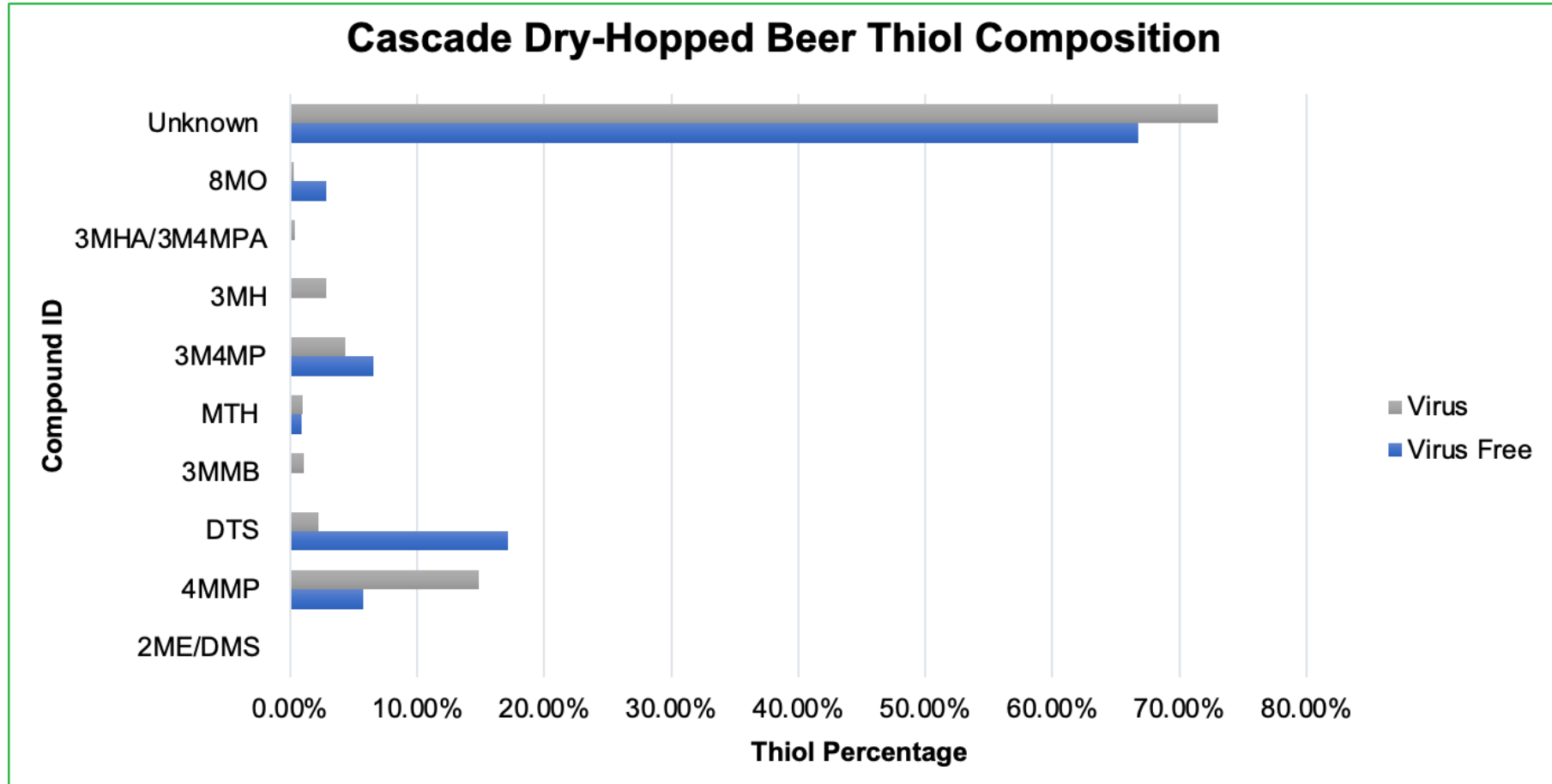
POLYFUNCTIONAL THIOLS - BEER

- Dry-hopping beers with virus-free Cascade hops led to a **decrease in 4MMP composition but an increase in 3MH composition** compared to those with virus-infected Cascade hops.
- Virus-infected Cascade hops resulted in a **larger number of detected thiols** in the beer compared to virus-free Cascade hops. This trend was also observed in Cascade pellets, with "normal" Cascade having more thiol composition, including unidentified ones.
- "Normal" Cascade hops **exhibited a higher level of 4MMP** compared to "Late" Cascade hops.

| Lot ID | DMS/2ME | 4MMP/MTI | DTS | 3M3MB | MTH | 3M4MP | 3MH | 3MHA/3M 4MPA | 8MO | Unidentified |
|-------------------------|---------|----------|--------|-------|-------|-------|-------|-----------------|-------|--------------|
| Virus Free Cascade Beer | 0.00% | 5.76% | 17.11% | 0.00% | 0.94% | 6.54% | 0.00% | 0.00% | 2.84% | 66.81% |
| Virus Cascade Beer | 0.00% | 14.88% | 2.21% | 1.11% | 0.96% | 4.30% | 2.81% | 0.37% | 0.28% | 73.08% |



CONT. BEER



TERPENES – HOPS & BEER

- Levels of **geraniol, limonene and linalool** were **higher** in the Virus Free Cascade dry-hopped beer than in the Virus Cascade dry-hopped beer. Both Virus Free and Virus Cascade beers were similar in levels of myrcene and β -pinene.

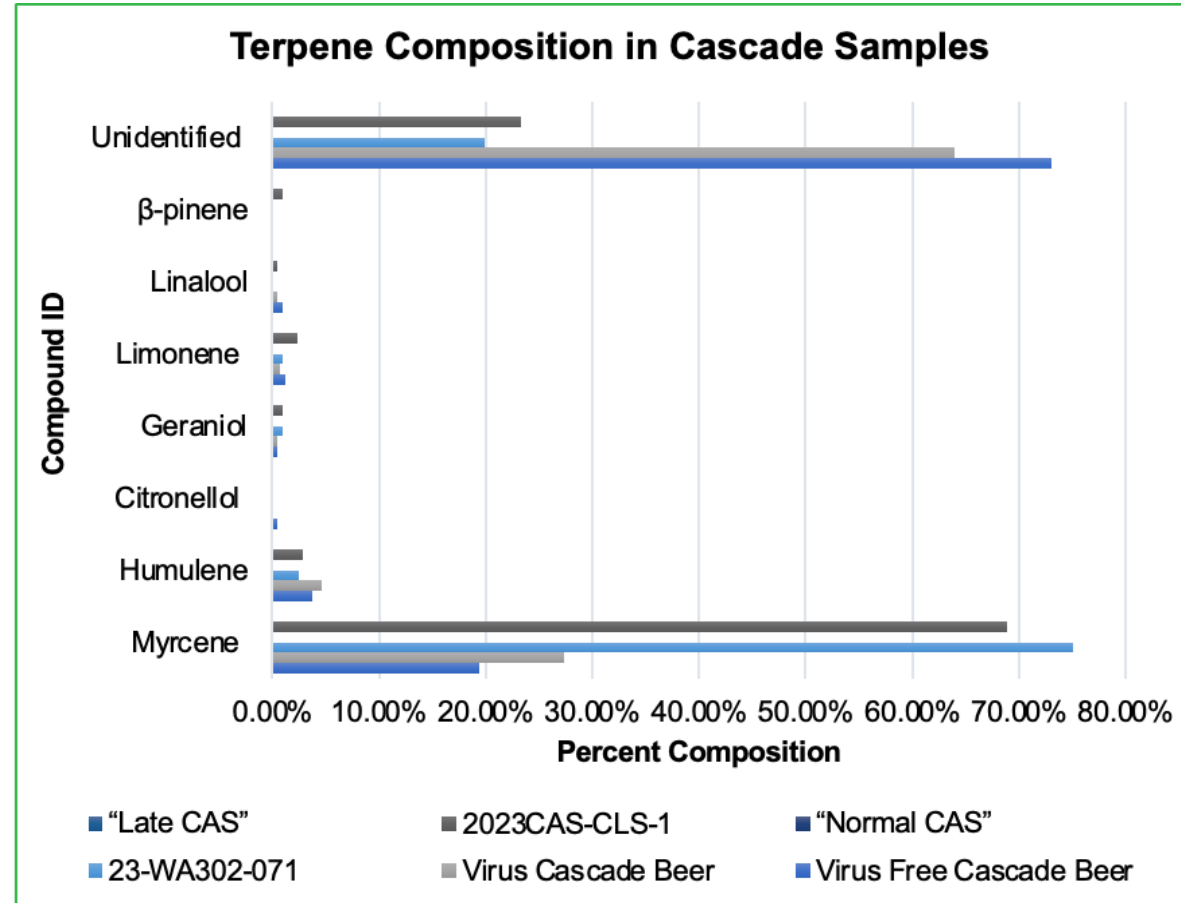


Figure 4. Percent composition of terpenes in Cascade beer and hop samples.

HOP CREEP & HARVEST WINDOWS



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HOP CREEP

Fermentable Sugar Contribution Post DH Reduction*

Amarillo (15g/L, 3.87 lb. / bbl.)

| Harvest Time | RE pick-up (P) |
|--------------|-----------------|
| Early 2018 | 0.415 +/- 0.007 |
| Mid 2019 | 0.395 +/- 0.007 |
| Late 2020 | 0.44 +/- 0 |

El Dorado (15g/L, 3.87 lb. / bbl.)

| Harvest Time | RE pick-up (P) |
|--------------|-----------------|
| Early 2022 | 0.405 +/- 0.007 |
| Mid 2022 | 0.40 +/- 0.02 |
| Late 2022 | 0.395 +/- 0.007 |

Extract from Hops: Fermentable Sugars are directly extracted from hops by any beer or liquid. Significant empirical evidence suggests 0.01 Plato is contributed to the liquid per 1 lb./bbl addition of whole cone or T90 hops. Extractable fermentable sugar fluctuates very little between crop year, harvest window or variety.

~1 lb./bll = 0.01 plato



HOP CREEP

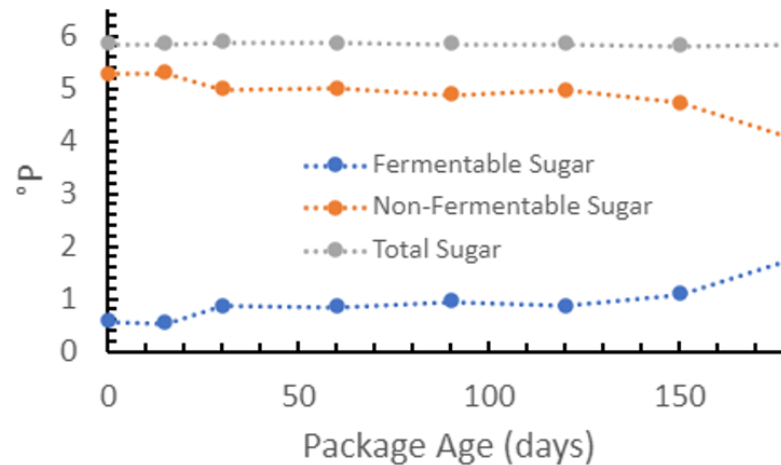
Maltose & Maltotriose Reduction Post DH – Evidence of Enzymes Activity

Amarillo (15g/L, 3.87 lb. / bbl.)

| Harvest Time | Maltose (P) | Maltotriose (P) |
|--------------|-------------|-----------------|
| Early 2018 | 0.10 | 0.04 |
| Mid 2019 | 0.12 | 0.05 |
| Late 2020 | 0.10 | 0.04 |

El Dorado (15g/L, 3.87 lb. / bbl.)

| Harvest Time | Maltose (P) | Maltotriose (P) |
|--------------|-------------|-----------------|
| Early 2022 | 0.19 | 0.06 |
| Mid 2022 | 0.18 | 0.06 |
| Late 2022 | 0.21 | 0.06 |



WHAT DOES THIS MEAN FOR YOU?



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RAW MATERIAL QUALITY MANAGEMENT

- Differentiate between hops from virus-infected and virus-free yards; ask vendors about the origin of hops to provide context on possible aroma differences.
- Harvest dates impact hop aromas; request harvest dates for spot purchases to make informed decisions OR request harvest dates at or before selection.
- Recognize your personal preferences as a brewer regarding harvest windows and aroma profiles; provide feedback to vendors for better selection. If purchasing on spot, request harvest dates and refer to as a guide for aroma quality.
- Collaborate or discuss with other brewers on harvest window preference if participating in a group selection; tailor selections to match your recipe requirements.

Highlights the importance of an internal sensory program for raw material quality management, which contributes to improved hop bills to maximize flavor and aroma targets.

Additional Resources



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THANK YOU!

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