



A 2023 Craft Brewers Conference® Seminar

FINDING THE EDGES

The Intersection of Art and Science for Hop-Picking Windows

PANELISTS

TOM NIELSEN, SIERRA NEVADA BREWING

ERIC DESMARAIS, CLS FARMS

ALEXANDRA NOWELL, CLS FARMS

STEPHANIE CONN, HOPTECHNIC

May 8, 2023 | 10:45–11:45 AM | Room 106ABC

Finding the Edge



- Pre 2012 vs. Post 2012
- Sierra Nevada/CLS feedback loop on hop picking windows – Finding the Edge
- Fixed vs. Dynamic picking dates – maturity is late, weather events, age of the yard makes a big difference, virus free



Harvest Time Windows Vary by *Region*

	Oregon	Washington	Idaho
Early	August 17	August 28	August 26
Middle	September 2	September 13	September 14
Late	September 13	September 24	September 26



Harvest Time Windows Vary by *Variety*

	WA-Cascade	WA-El Dorado®	WA-Amarillo®
Early	September 2	September 10	September 3
Middle	September 10	September 16	September 12
Late	September 18	September 20	September 18



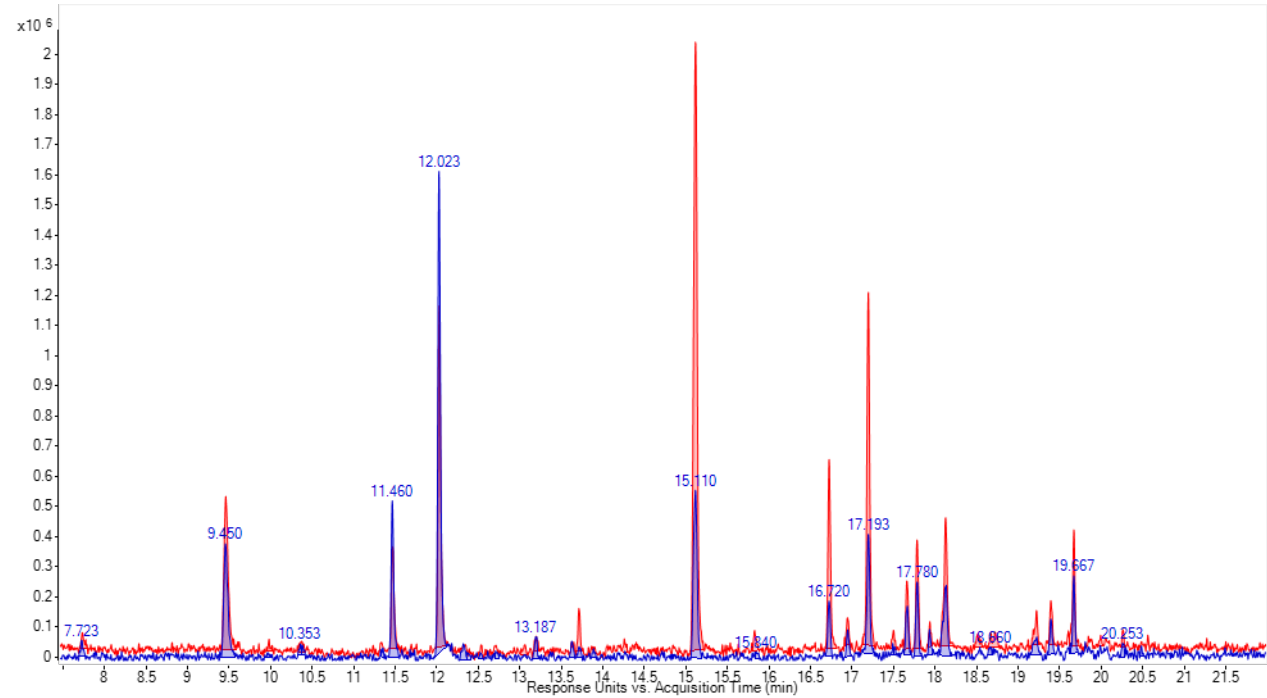
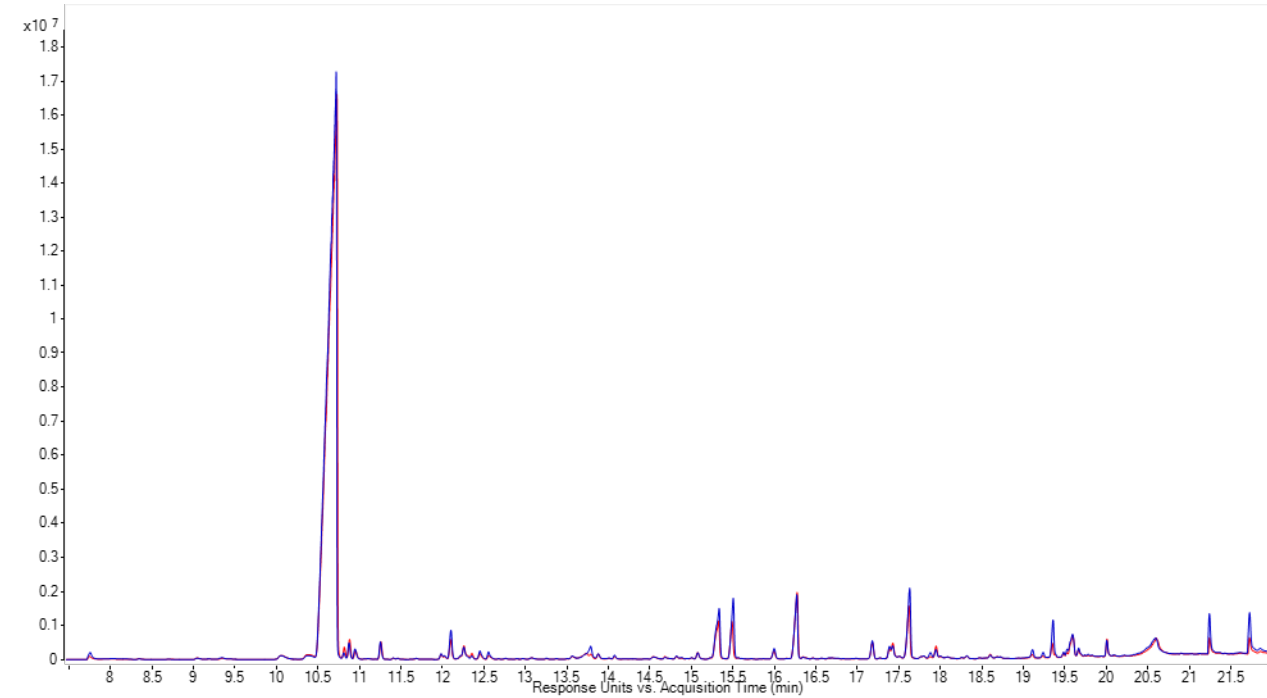
CLS Farms In-Field Sensory

- Consists of multiple people: Eric, Reid Lundgren, Alexandra Nowell
- Quick assessment for quick decisions
- Historical context
- Training dates

Pre vs. Post Harvest Assessment →
Timing Based on Brewery Feedback



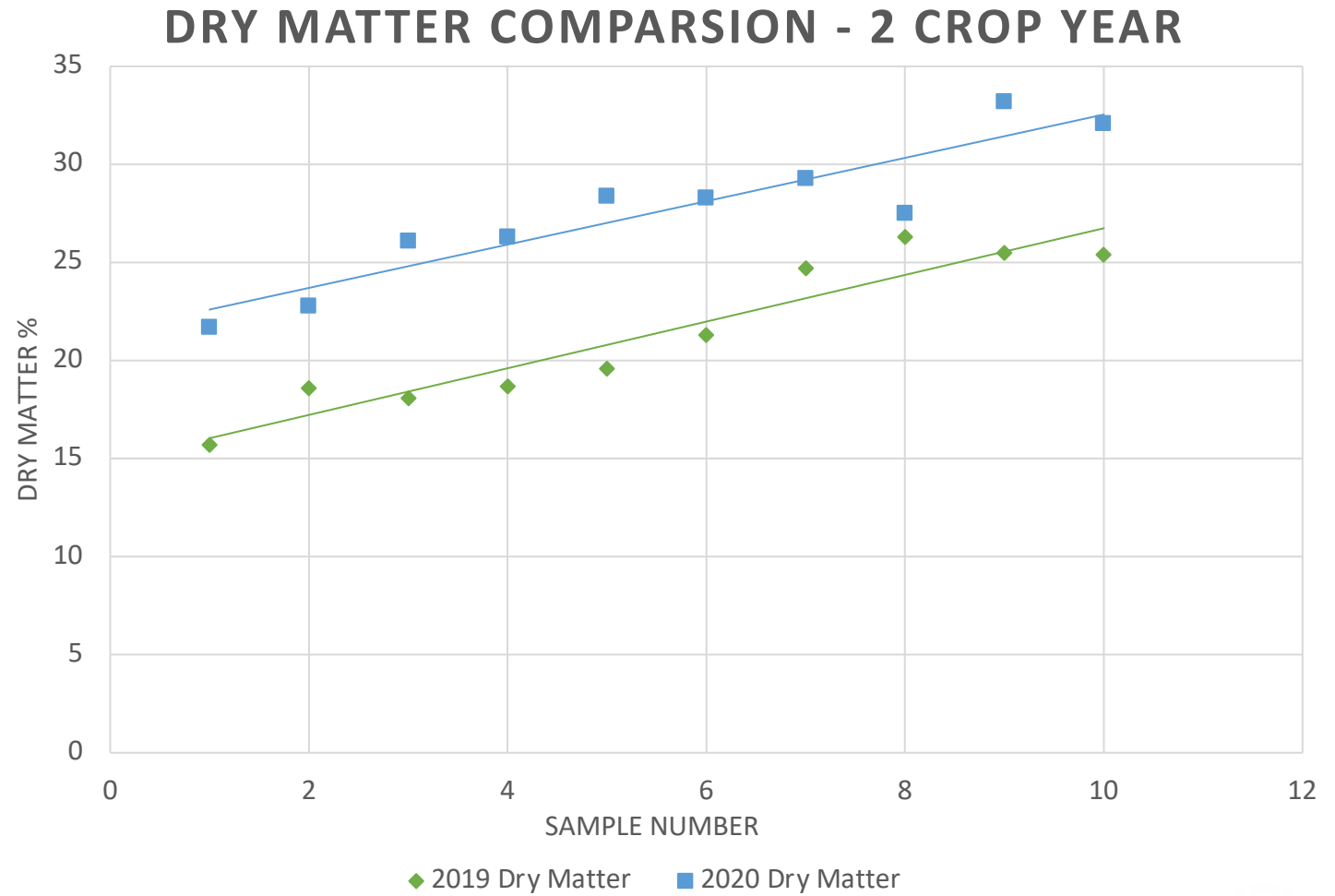
HopTechnic® Harvest Timing Program



	Terpene Confidence Score	Free Thiol Confidence Score
Farm A compared to Farm B	0.96	0.73

Targeting Aroma Profiles

- Pros & cons of targeting aroma profiles
- Dry matter content
- Terpenes and polyfunctional thiols
- Harvest window duration
 - Variety dependent



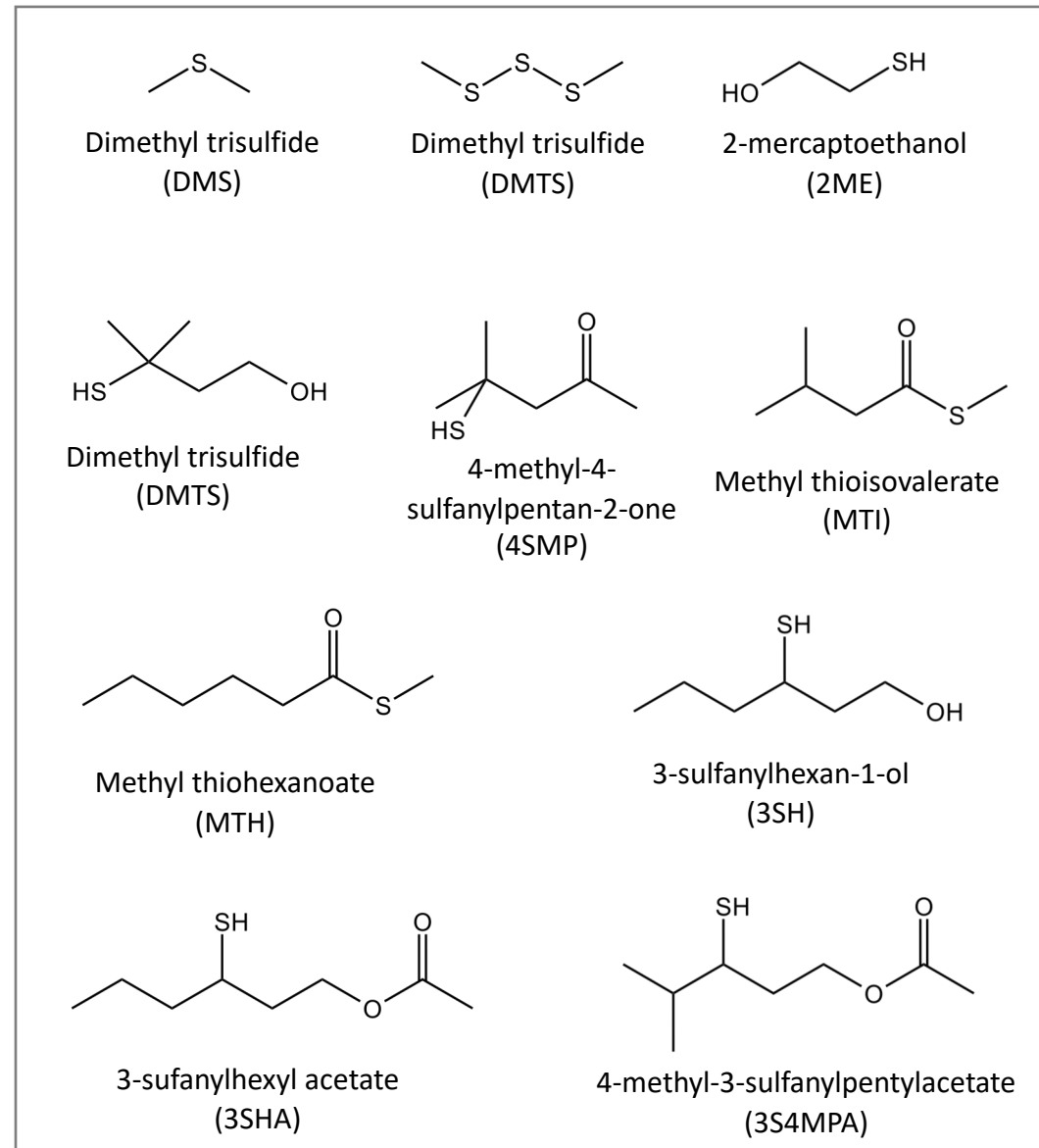
A wooden cutting board with several slices of blood orange and a white citrus squeezer. The background is a dark blue surface with some dried grasses in the bottom right corner.

Polyfunctional Thiol Chemistry



Free Thiols in Hops

- Thiol compounds tracked by Hoptechnic®:
 - 2ME/DMS** – 2-mercaptoethanol/dimethyl sulfide: grilled, gas/ vegetal, cooked corn
 - 4SMP(4MMP)/MTI** – 4-sulfanyl-4-methylpentan-2-one/methyl thioisovalerate: catty, black currant/ cheesy, fermented fruit
 - DMTS** – dimethyl trisulfide: savory, garlic, sulfurous
 - 3S3MB (3M3MB)**– 3-methyl-3-sulfanyl-butan-1-ol: savory, soup
 - MTH** – methyl thiohexanoate: guava, passionfruit, grapefruit
 - 3SH (3MH)** – 3-sulfanylhexasn-1-ol: passionfruit, guava, tropical, grapefruit
 - 3SHA (3MHA)** – 3-sulfanylhexasn-1-yl acetate: passionfruit, black currant, tropical



Effect of “Late Harvest” of Hops (*Humulus lupulus* L.) on the Contents of Volatile Thiols in Furano Beauty, Furano Magical, and Cascade Varieties

Mitsuhiro Uemoto,* Kiyoshi Takoi, Atsushi Tanigawa, Koji Takazumi, Kensuke Ogushi, Koichiro Koie, and Narushi Suda

 Cite This: *J. Agric. Food Chem.* 2022, 70, 607–614

 Read Online

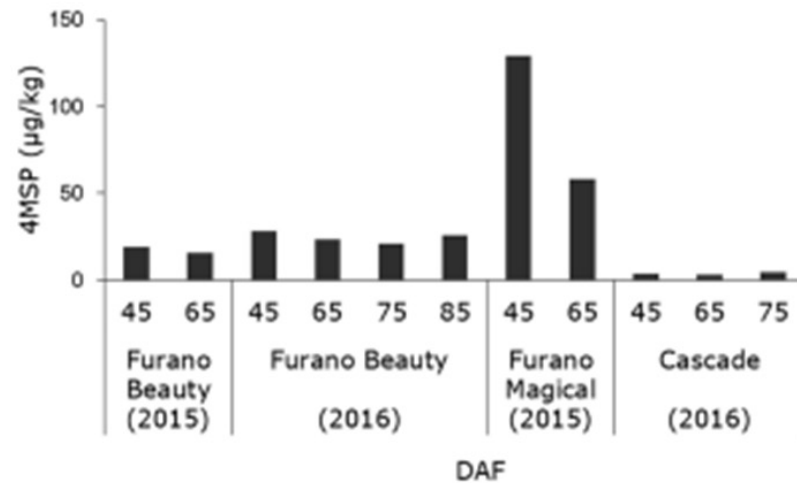


Figure 2. Concentrations of 4MSP in hop cones. DAF, days after flowering and 4MSP, 4-methyl-4-sulfanyl-pentane-2-one.

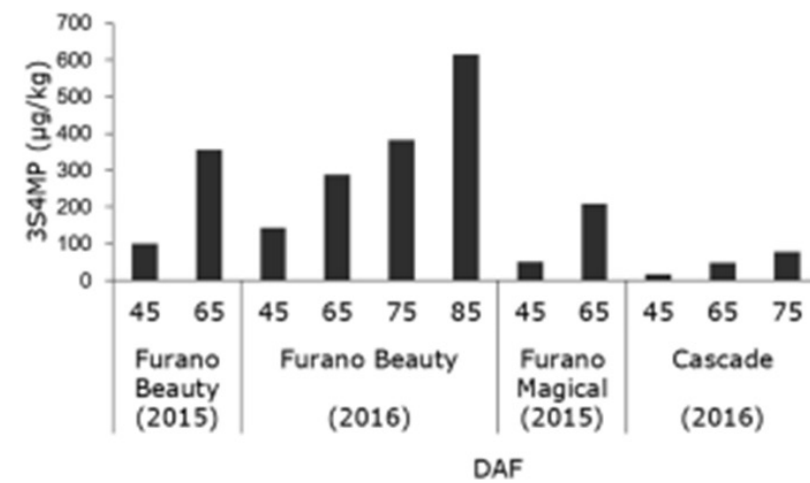


Figure 3. Concentrations of 3S4MP in hop cones. DAF, days after flowering and 3S4MP, 3-sulfanyl-4-methyl-pentane-1-ol.



Curious Case of 2020 Eureka! (tm)

CY	Variety	4MMP(ng/g)	3SH(ng/g)	3S4MP(ng/g)
2020	Eureka! EARLY	15.2	2.9	24.5
2020	Eureka! MID	15.3	2.7	29.7
2020	Eureka! LATE	15.8	2.7	28.8

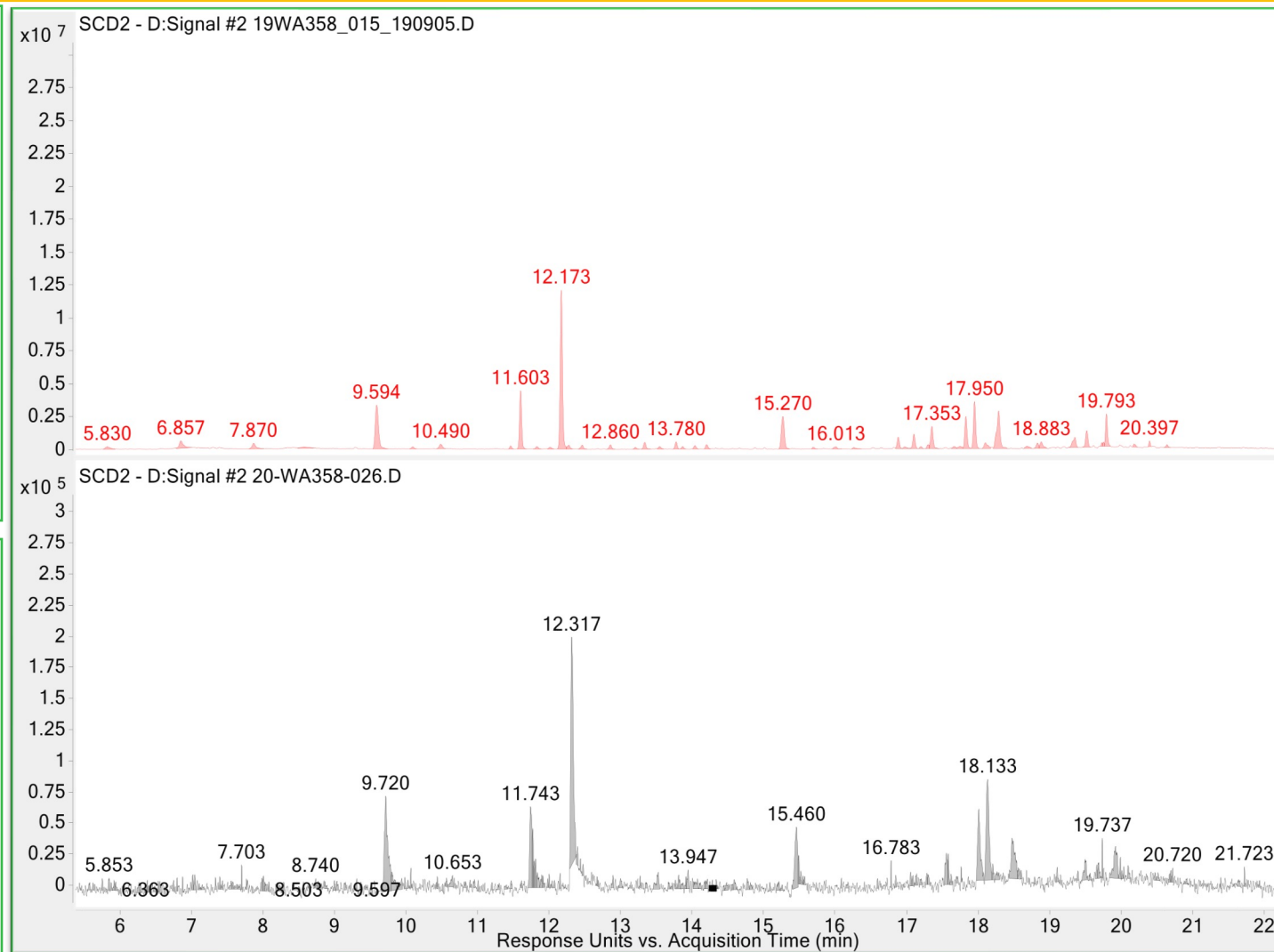
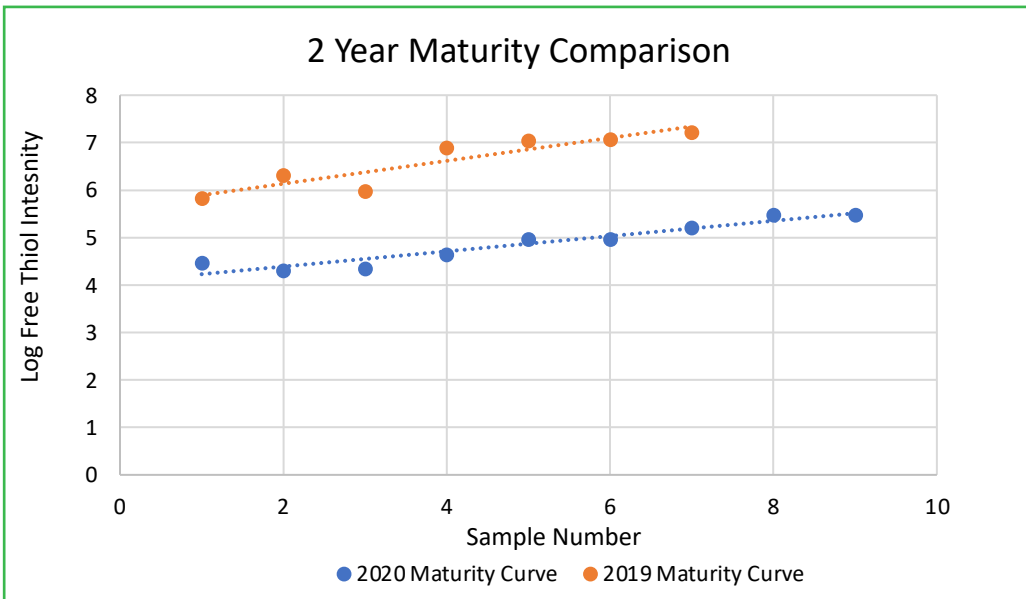
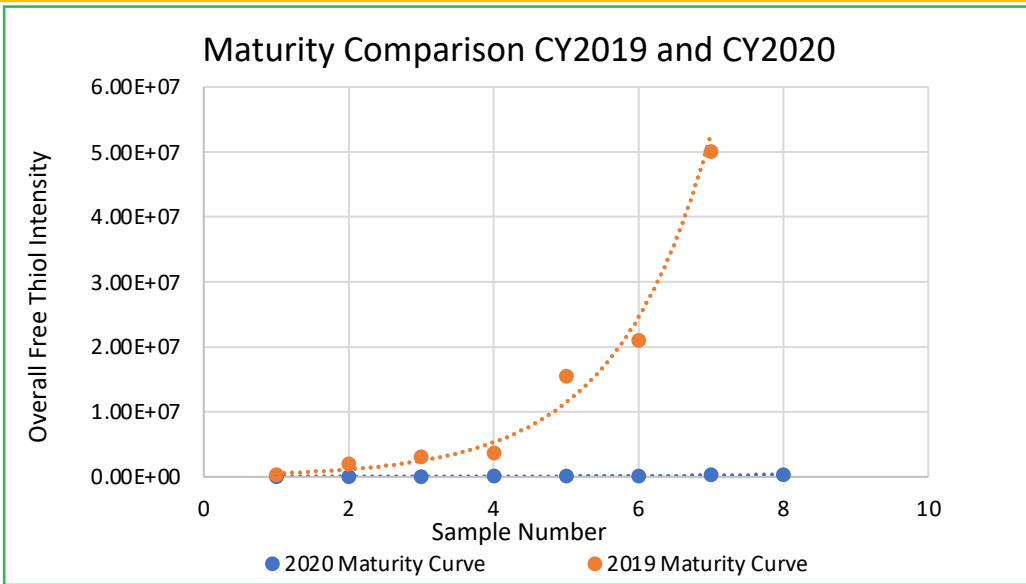


El Dorado® Thiols Content

CY	Variety	4MMP(ng/g)	3SH(ng/g)	3S4MP(ng/g)
2018	El Dorado	0.5	0.5	0.5
2020	El Dorado	0.9	1.1	3



Dynamic Harvest Windows



Geraniol Chemistry



Biotransformation of Hop-Derived Monoterpene Alcohols by Lager Yeast and Their Contribution to the Flavor of Hopped Beer

KIYOSHI TAKOI,^{*,†,‡} KOICHIRO KOIE,[§] YUTAKA ITOGA,[§] YUTA KATAYAMA,[‡]
MASAYUKI SHIMASE,[†] YASUYUKI NAKAYAMA,[†] AND JUNJI WATARI[†]

[†]Value Creation Department, and [‡]Frontier Laboratories of Value Creation, Sapporo Breweries Ltd., 10 Okatohme, Yaizu, Shizuoka 425-0013, Japan, and [§]Bioresources Research & Development Department, Sapporo Breweries Ltd., 3-5-25 Kamifurano-cho Motomachi, Sorachi-gun, Hokkaido 071-0551, Japan

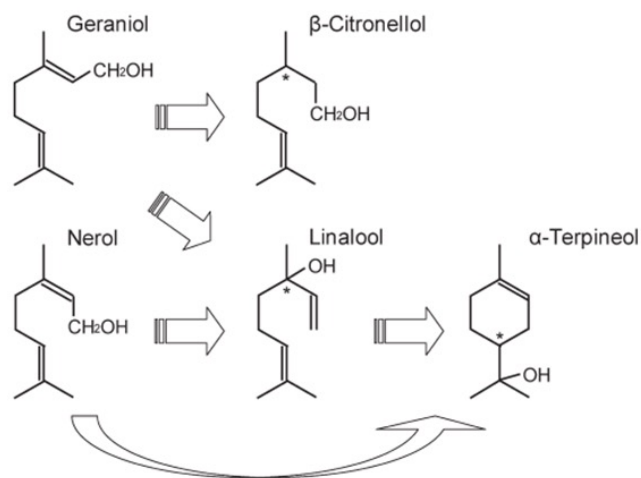
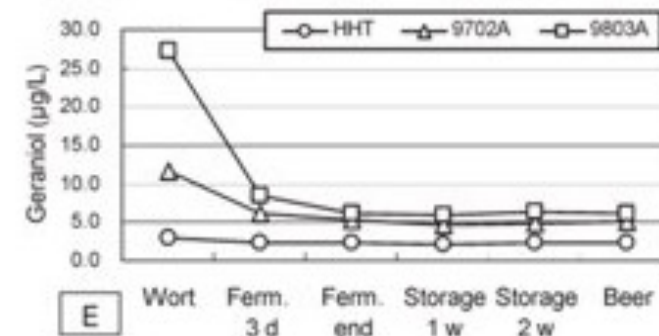
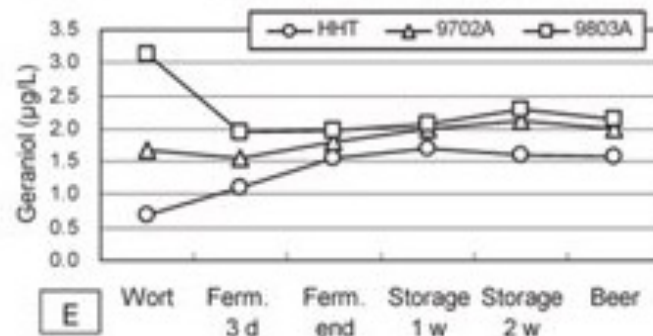
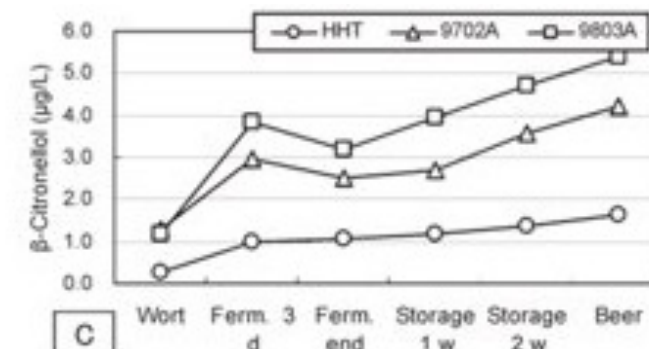
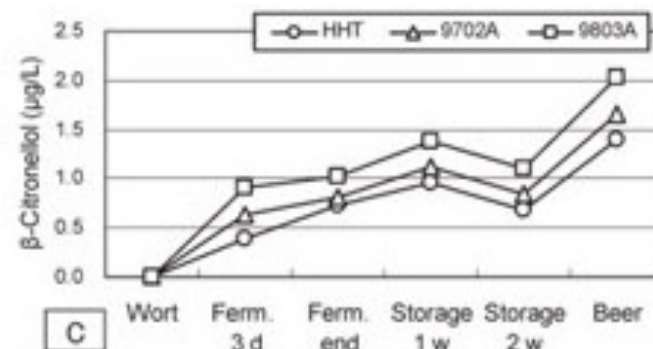
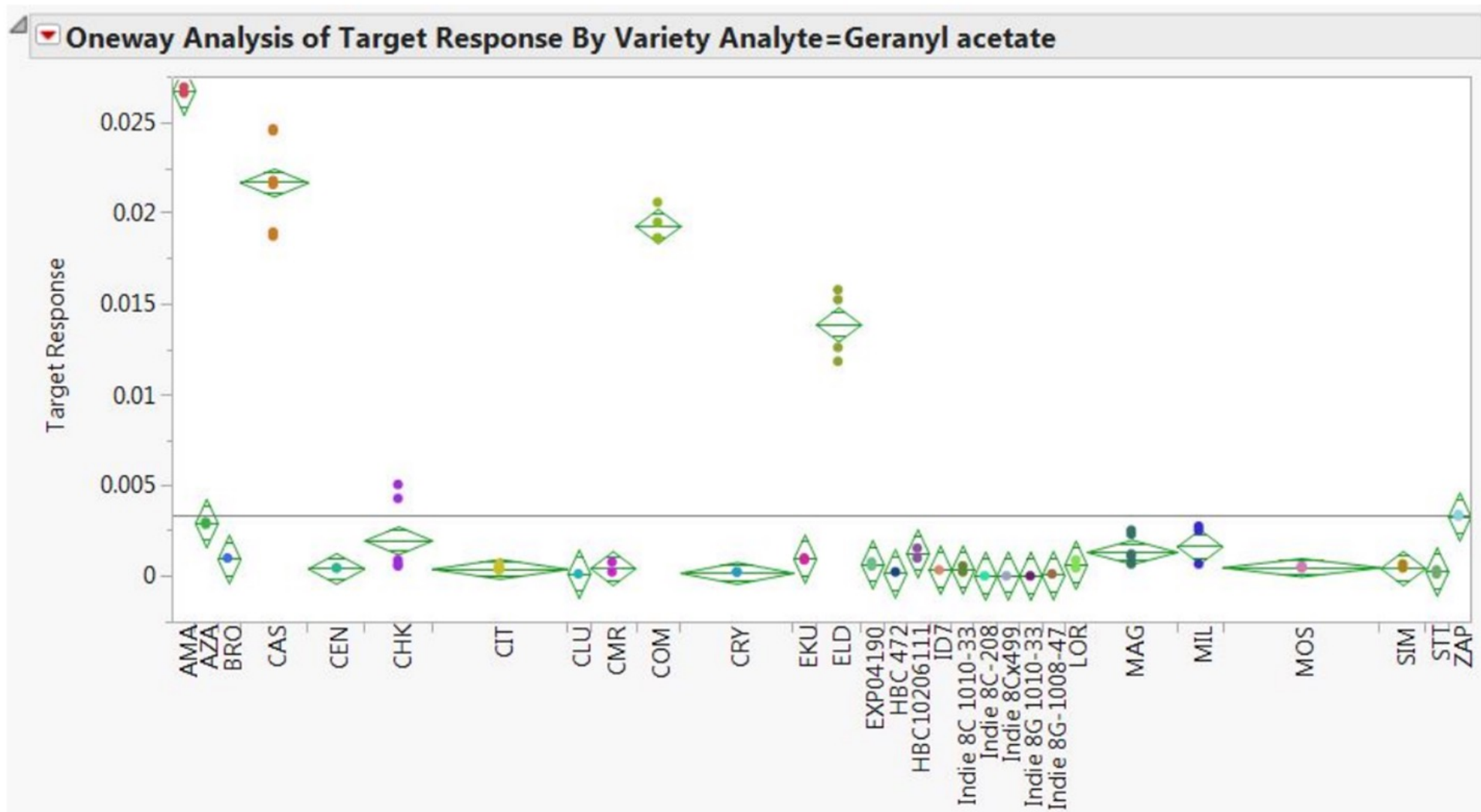


Figure 2. Metabolism cascade of monoterpene alcohols by lager and ale yeast (proposed by King et al. (13, 14)). An asterisk indicates a chiral center.

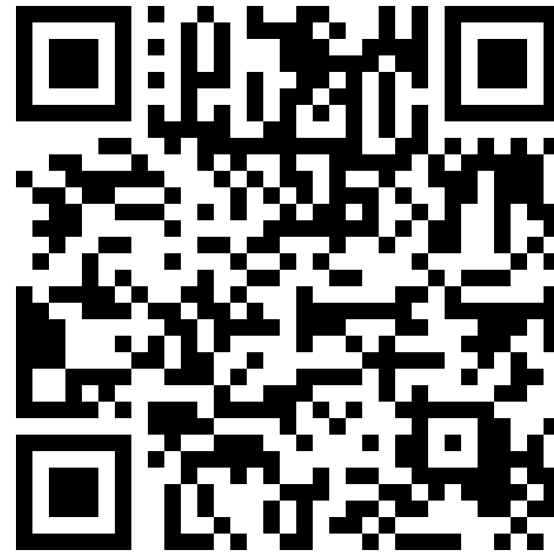


SNBCo. R&D – Geranyl Esters



Sensory

Sample
Ox 



JOIN CODE: 69419

Early Harvest – El Dorado®

Picking Window - September

Post Citra® – later is better than early.

GREEN = **Early Maturity**

Aroma notes: citrusy, brighter

YELLOW = **Middle Maturity**

Aroma notes: melon/watermelon, pear

ORANGE = **Peak Maturity**

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



September

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		



- Early harvested CTZ (heavy ruby red fruit, grapefruit, zest, tangerine)
 - Pushing the boundaries of a defined picking window
 - Flexibility
- Agronomic impact
 - Possible yield impact



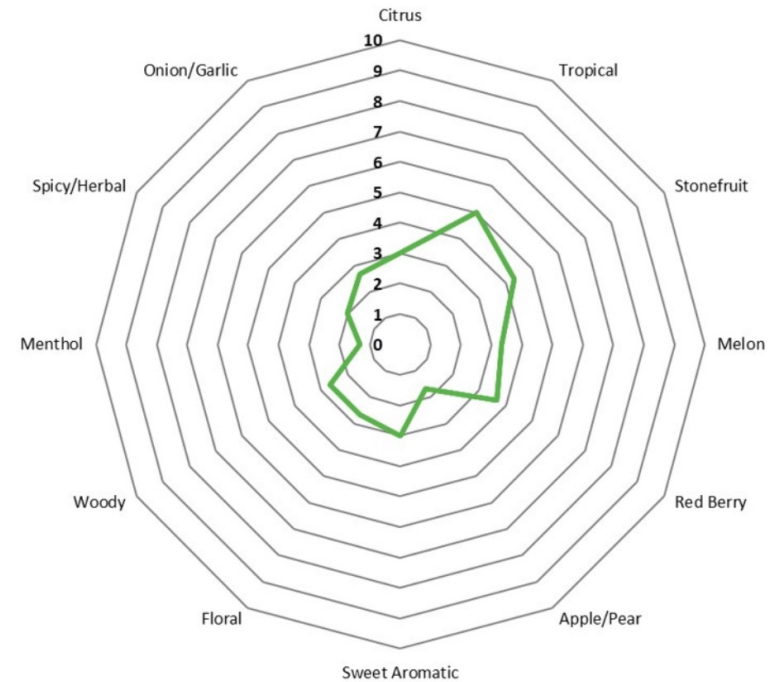
Early Harvest – El Dorado®

GREEN = Early Maturity
Aroma notes: citrusy, brighter

- Candied lemon, orange, slightly greener

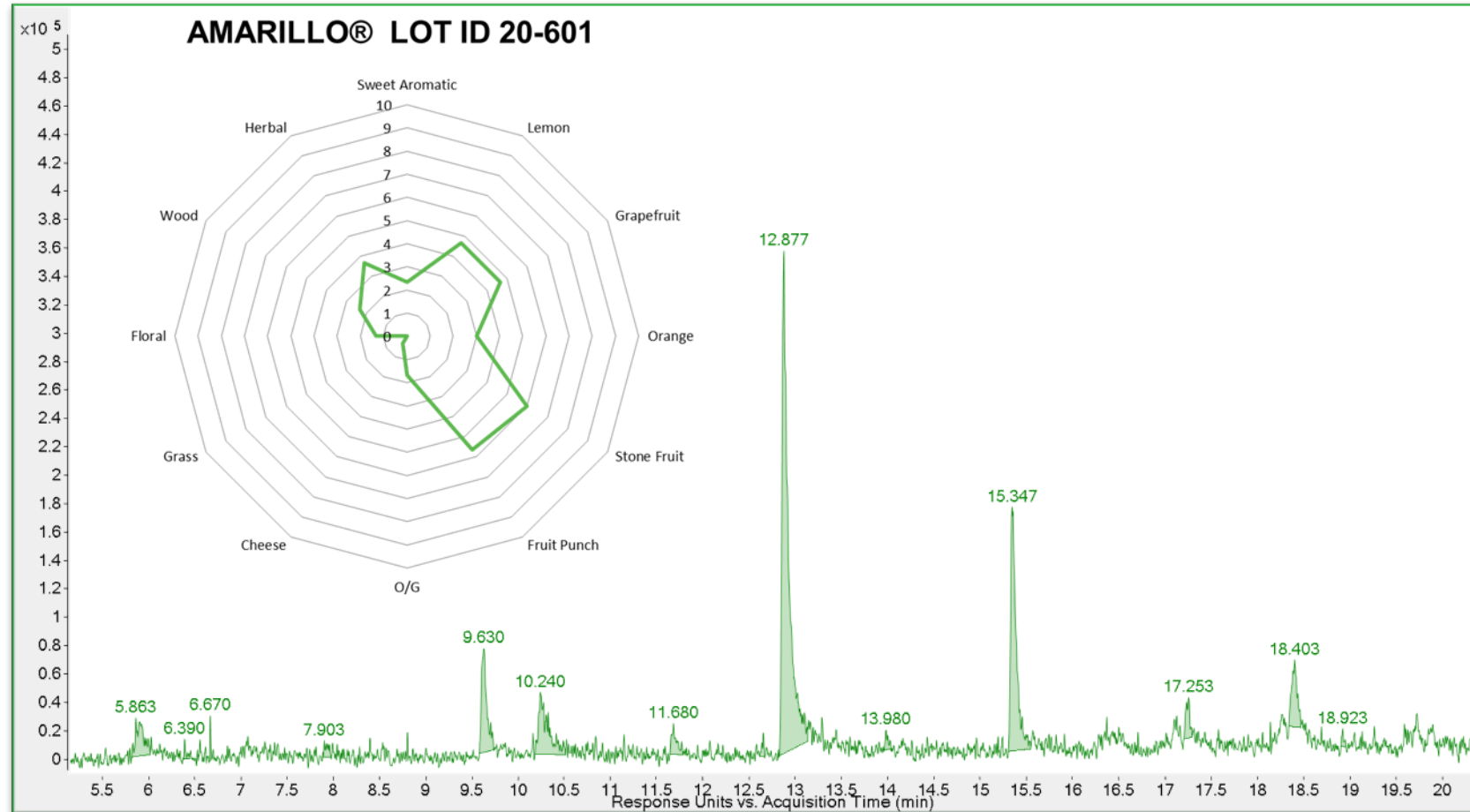
Aroma Compound	% of Thiols
2-mercaptoethanol/ dimethyl sulfide (1)	14.58%
4-mercapto-4-methylpentan-2-one/ Methyl isothiovalerate (2)	24.03%
Dimethyl trisulfide (3)	0.26%
3-mercapto-3-methylbutan-1-ol (4)	8.64%
Methyl thiohexanoate (5)	15.68%
3-mercapto-4-methyl pentanol (6)	3.00%
3-mercapto-hexan-1-ol (7)	0.00%
3-mercapto-4-methyl-pentylacetate/ 3-mercaptohexyl acetate (8)	0.86%
8-mercapto-octan-1-ol (9)	1.35%
Unidentified	31.60%

EL DORADO® LOT ID 22-WA405-034 (22C1ELD11)



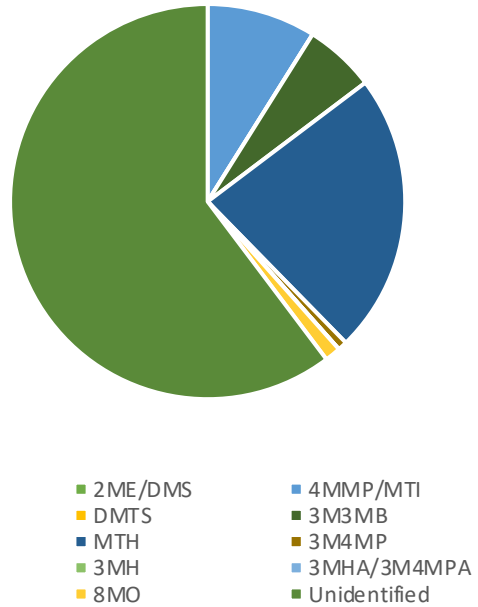
Early Harvest Profile – Amarillo®

- Early harvest:
 - VG1: Lemon, sweet candy, floral
- Most often harvested as an “Early-mid”
 - Grapefruit, lemon, floral, herbal, slightly sweet, little to no o/g
- Early harvest aromas typically exhibit sweeter and more floral/herbal aroma than later harvest

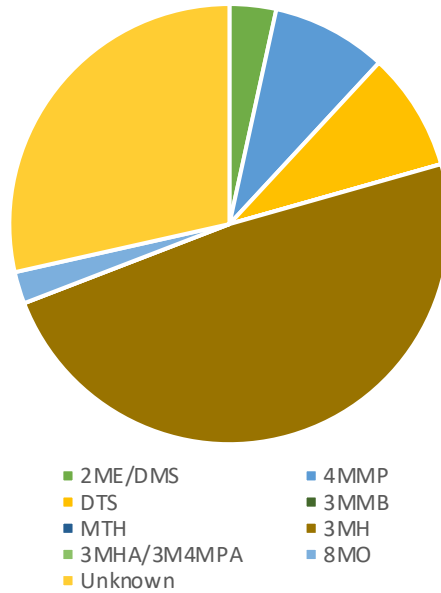


Early Harvest Profile – Amarillo®

19-WA358-005



20-601



Compound	19-WA358-005	20-601
2ME/DMS	0.00%	3.43%
4MMP/MTI	8.92%	8.47%
DMTS	0.00%	8.71%
3M3MB	5.79%	0.00%
MTH	22.95%	0.00%
3M4MP	0.77%	48.54%
3MH	0.00%	0.00%
3MHA/3M4MPA	0.00%	0.00%
8MO	1.29%	2.35%
Unidentified	60.27%	28.51%

Mid Harvest – El Dorado®

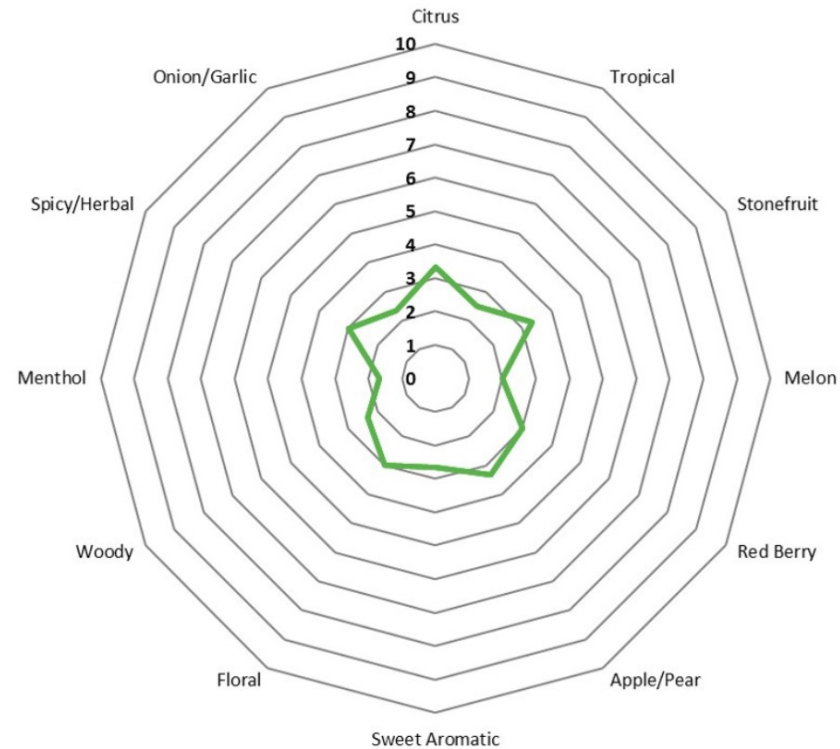
YELLOW = Middle Maturity

Aroma notes: melon/watermelon, pear

- Watermelon jolly rancher, green fruit

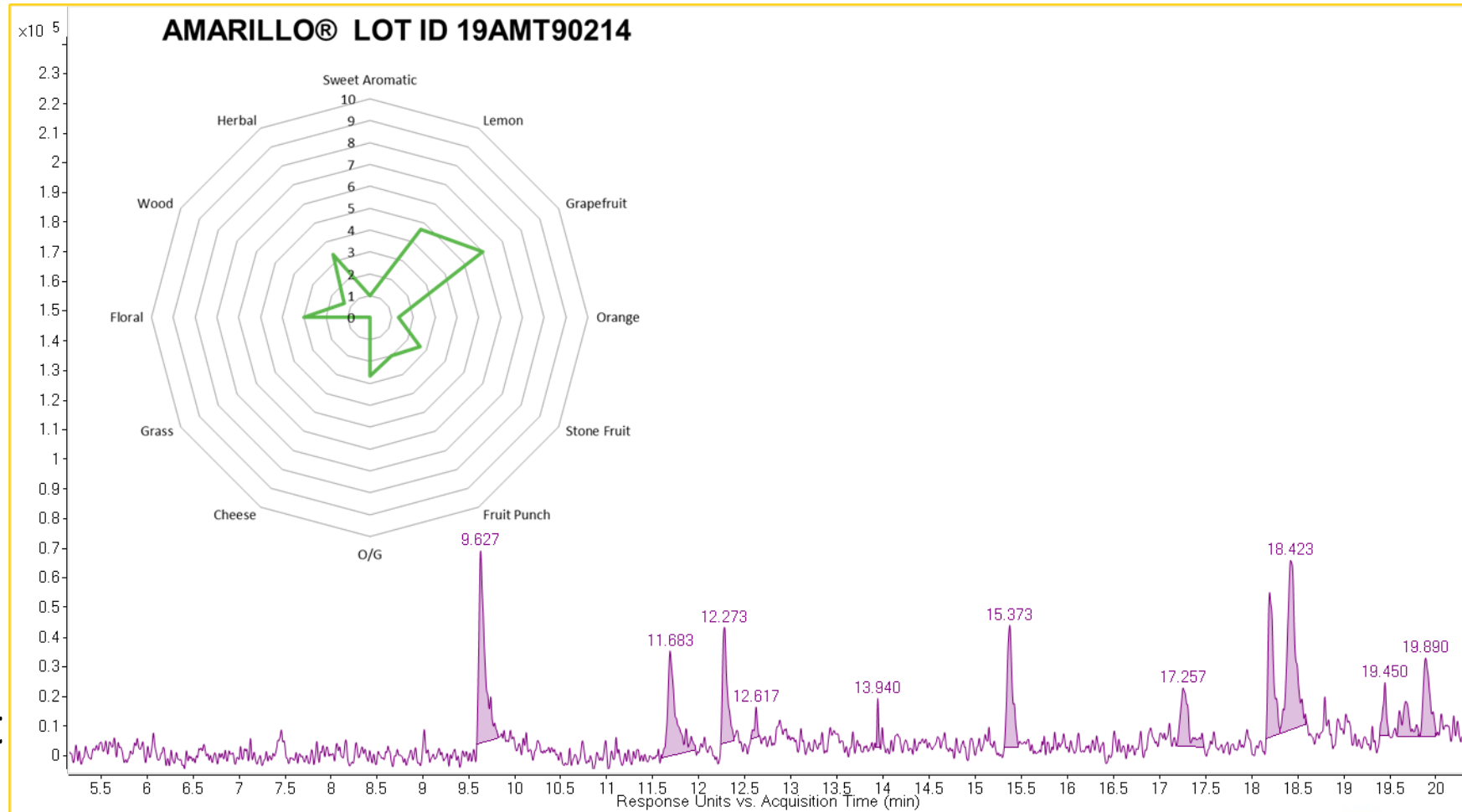
Aroma Compound	% of Thiols
2-mercaptoethanol/ dimethyl sulfide (1)	5.04%
4-mercapto-4-methylpentan-2-one/ Methyl isothiovalerate (2)	12.43%
Dimethyl trisulfide (3)	0.00%
3-mercapto-3-methylbutan-1-ol (4)	5.50%
Methyl thiohexanoate (5)	12.85%
3-mercapto-4-methyl pentanol (6)	1.27%
3-mercapto-hexan-1-ol (7)	0.00%
3-mercapto-4-methyl-pentylacetate/ 3- mercaptohexyl acetate (8)	0.34%
8-mercapto-octan-1-ol (9)	0.47%
Unidentified	62.10%

EL DORADO® LOT ID 22-WA360-031 (22C2ELD11)



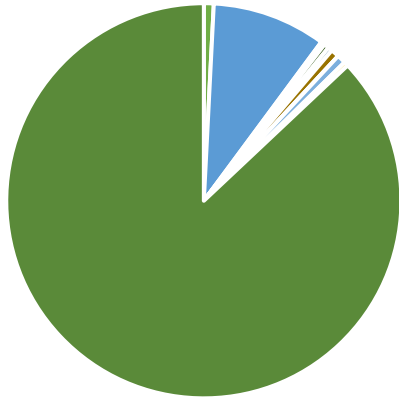
Mid Harvest Profile – Amarillo®

- Mid harvest
 - VG1: Citrus, stone fruit and fruit punch, herbal/floral, more pronounced o/g
- In general, more perceived depth in aroma, often much more prominent aroma intensity
- Varieties prone to development of onion/garlic aromas start to develop in this region



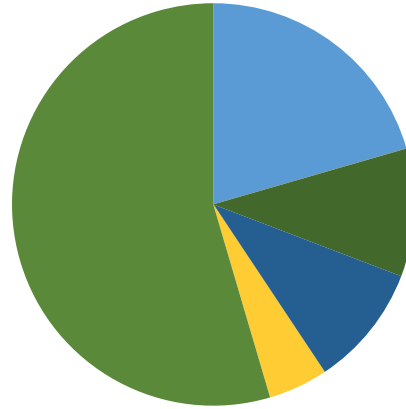
Mid Harvest Profile – Amarillo®

19-WA358-015



- 2ME/DMS
- 4MMP/MTI
- DMTS
- 3M3MB
- MTH
- 3M3MP
- 3MH
- 3MHA/3M4MPA

19AMT90214



- 2ME/DMS
- 4MMP
- DTS
- 3MMB
- MTH
- 3M4MP
- 3MH
- 3MHA/3M4MPA
- 8MO
- Unknown

Compound	19-WA358-015	19AMT90214
2ME/DMS	0.81%	0.00%
4MMP/MTI	9.33%	20.52%
DMTS	0.32%	0.00%
3M3MB	0.41%	10.29%
MTH	0.35%	9.85%
3M4MP	0.68%	0.00%
3MH	0.00%	0.00%
3MHA/3M4MPA	0.72%	0.00%
8MO	0.35%	4.78%
Unidentified	87.02%	54.56%

Sensory

Sample
Ox 



JOIN CODE: 69419

Late Harvest – El Dorado®

ORANGE = Peak Maturity

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

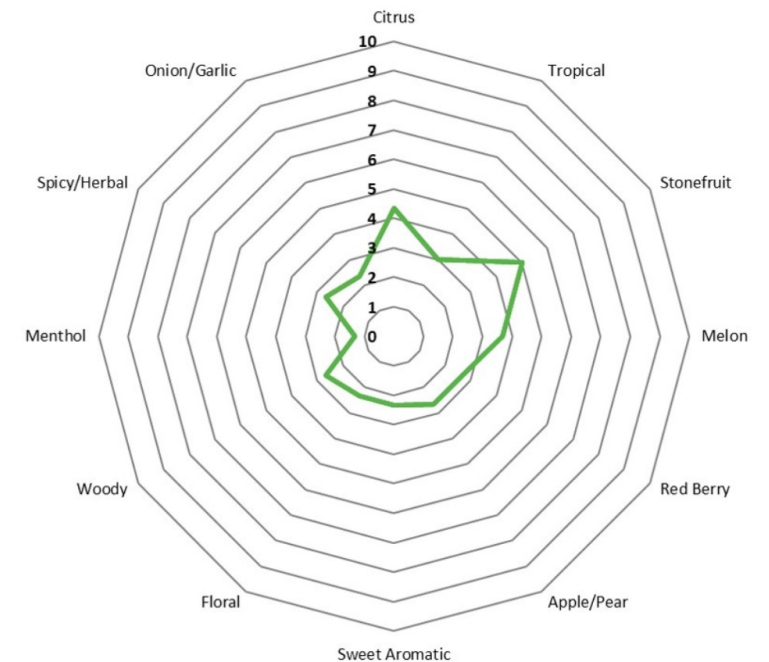
- Pineapple, apricot, cherry, watermelon, Peachie Rings, fruity pebbles, sweet fruit, mango

Physical Indicators:



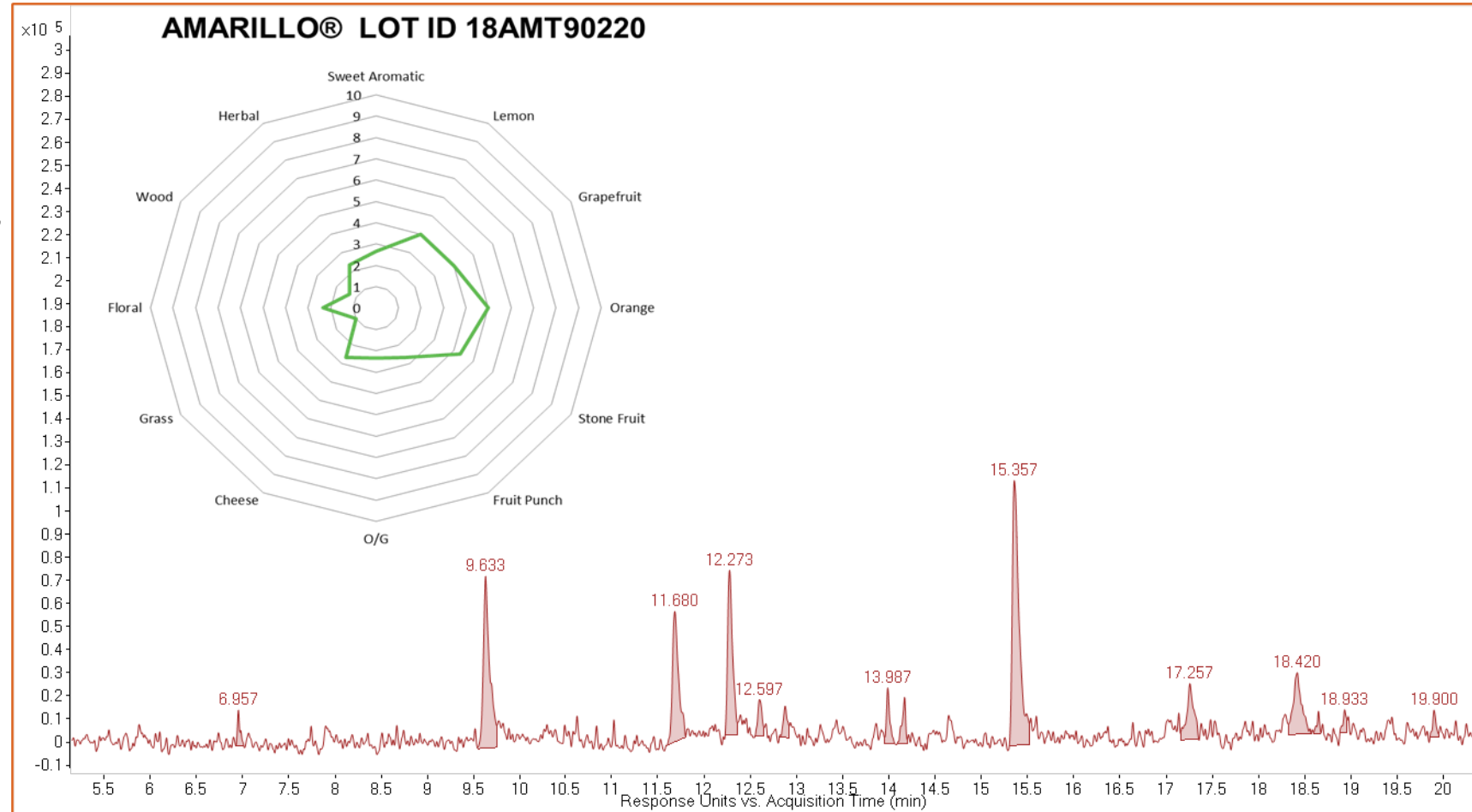
Aroma Compound	% of Thiols
2-mercaptoethanol/ dimethyl sulfide (1)	25.77%
4-mercapto-4-methylpentan-2-one/ Methyl isothiovalerate (2)	29.72%
Dimethyl trisulfide (3)	0.34%
3-mercapto-3-methylbutan-1-ol (4)	4.75%
Methyl thiohexanoate (5)	0.00%
3-mercapto-4-methyl pentanol (6)	5.02%
3-mercapto-hexan-1-ol (7)	0.00%
3-mercapto-4-methyl-pentylacetate/ 3-mercaptohexyl acetate (8)	0.73%
8-mercapto-octan-1-ol (9)	0.60%
Unidentified	33.08%

EL DORADO® LOT ID 22-WA405-054 (ELD-2201)



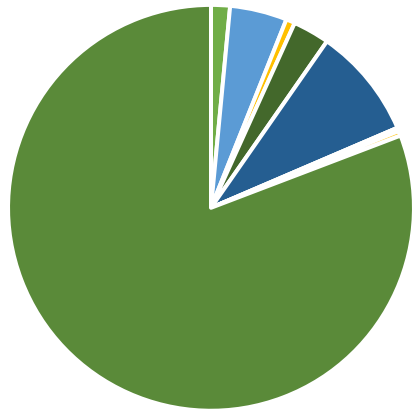
Late and Mid-Late Harvest Profile – Amarillo®

- Late harvest
 - VG1: Citrus (muddled), stone fruit, fruit punch, herbal, heavier onion/garlic, aged cheddar
- Typically characterized by more prominent “dank” notes



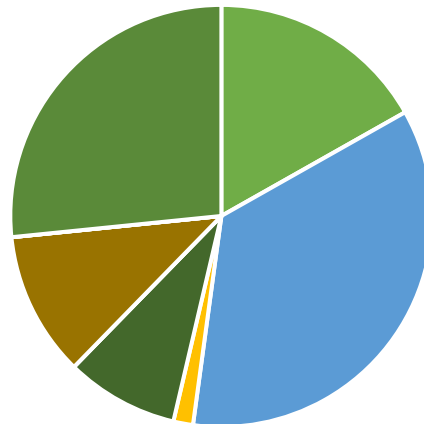
Late and Mid-Late Harvest Profile – Amarillo®

19-WA337-016



- 2ME/DMS
- DMTS
- MTH
- 3MH
- 8MO
- 4MMP/MTI
- 3M3MB
- 3M3MP
- 3MHA/3M4MPA
- Unidentified

18AMT90220



- 2ME/DMS
- DTS
- MTH
- 3MH
- 8MO
- 4MMP
- 3MMB
- 3M3MP
- 3MHA/3M4MPA
- Unidentified

Compound	19-WA337-016	18AMT90220
2ME/DMS	1.51%	16.82%
4MMP/MTI	4.55%	35.33%
DMTS	0.71%	1.50%
3M3MB	2.91%	8.65%
MTH	8.87%	0.00%
3M4MP	0.00%	11.08%
3MH	0.27%	0.00%
3MHA/3M4MPA	0.00%	0.00%
8MO	0.39%	0.00%
Unidentified	80.79%	26.61%



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 0.1 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. / bbl. DH = ~0.1 Plato Fermentables



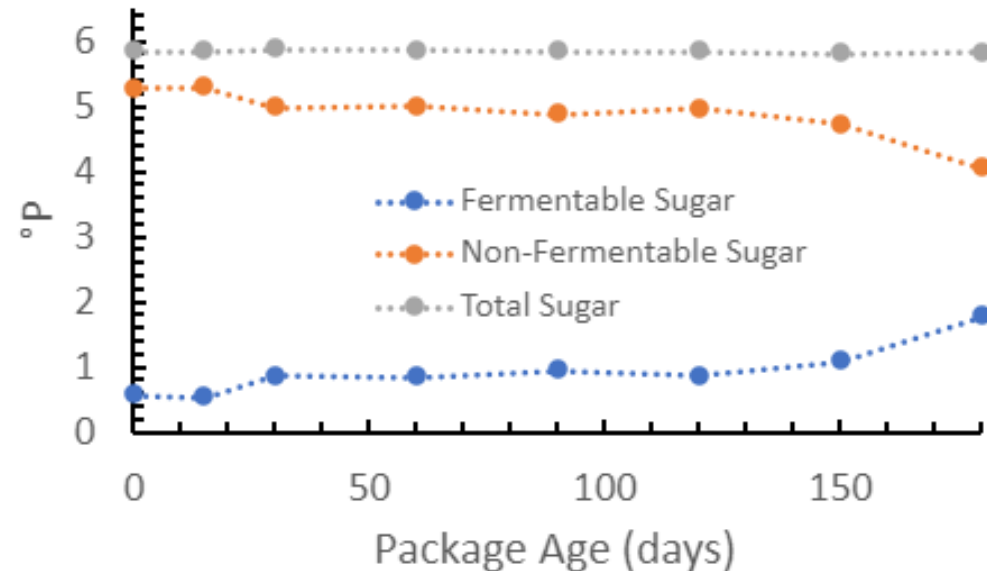
Maltose & Maltotriose Reduction Post DH – Evidence of Enzymes Activity

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



Summary

Highlights

- In-field sensory gives flexibility and speed
- CLS is moving towards a blend of the two
- Harvest windows are dynamic & shift based on natural events
- Analytics can help navigate aroma variances between crops years, especially when paired with traditional sensory



El Dorado®

Early: Citrus lemon, orange, greener

Mid: Watermelon, jolly rancher, pear, green fruit

Late: Sweet fruit, pineapple, mango, cherry, candy, fruity pebbles



Amarillo®

Early: Lemon, sweet candy, floral

Mid: Citrus, stone fruit and fruit punch, herbal/floral, more pronounced o/g

Late: Citrus (muddled), stone fruit, fruit punch, herbal, heavier onion/garlic, aged cheddar



Thank you!



***SCAN TO RECEIVE A COPY OF THE
PRESENTATION***