



**HOP &  
BREW  
SCHOOL**



**NEXT GEN HOP AROMA: A FOCUS ON THE SCIENCE OF**

**SURVIVABLE COMPOUNDS**

# PRESENTERS



Spencer Tielkemeier is the Director of Sales- North America for Yakima Chief Hops. He spent 9 years in as a production brewer in Austin, TX, specializing in hop-forward and continental lager styles. Since joining YCH, Spencer has been a key part of their Brewing Innovations team, developing new products, honing best-practices for product usage, and providing tailored customer support in challenging product application scenarios. Spencer believes the best beer pairing is made where hops meet disc golf. He lives in Yakima, WA with his wife, daughter, son, and dog.



Kelly Lohrmeyer is a Field Market Manager Yakima Chief Hops. Kelly began working with YCH in August of 2015, for the State of California including the Island of Hawaii. Over time team members have been added to our Family and Kelly was moved into the Role of Field Marketing West. Kelly started her journey in beer long ago. Being part of monumental growth and change in the Craft Beer/Food Industry, has been a passion of Kelly's. She is excited to be a part of connecting the world's Brewers with our Growers through education and partnership in collaborations, events, and contract guidance.

# CULTURE OF INNOVATION

## PEOPLE

- Expanded R&D Lab and Sensory teams with experienced hop and beer staff

## FACILITIES

- State-of-the-art R & D lab responsible for creating and refining analytical standards in the hop industry
- Research brewery conducts continuous product trialing, allowing constant improvement of YCH products

Together the talented R & D team dedicated to solutions and novel brewing innovations led to the survivables research – specifically beer soluble compounds.

The supportive and creative environment allows YCH to enrich our entire supply chain through industry-leading hop discoveries.





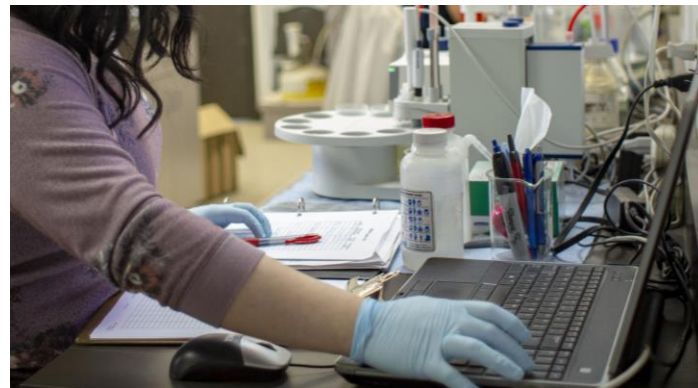
# SURVIVABLE COMPOUNDS

## RESEARCH & DEVELOPMENT

- R & D Team utilizing cutting-edge hop analysis techniques to study and detect maximum potential of aroma hops.
- Discovered the hop survivor technology while exploring aroma potential of novel hop compounds – specifically beer-soluble compounds.
- Beer Soluble Hop Compound Research creates a framework for brewers to select and utilize varieties to their maximum effect.
- Helps to bridge the gap between raw hop aroma and finished beer aroma.

## GROWER NETWORK

- 40 million+ lbs of harvest bales allows YCH to choose the perfect, most impactful blend components



# HOP OIL COMPONENTS

## OVER 1,000 DIFFERENT COMPOUNDS

- Terpenes (Hydrocarbons)
  - Monoterpenes 40%
  - Sesquiterpenes 40%
  - Aliphatic Hydrocarbons <1% (straight chains nonaromatic rings)
- Oxygenated Derivatives
  - Esters 15%
  - Carboxylic acid 1%
  - Monoterpene Alcohols 1%
  - Sesquiterpene Oxides 1%
  - Aldehydes and Ketones 1%
  - Thiols (sulfur-containing compounds)



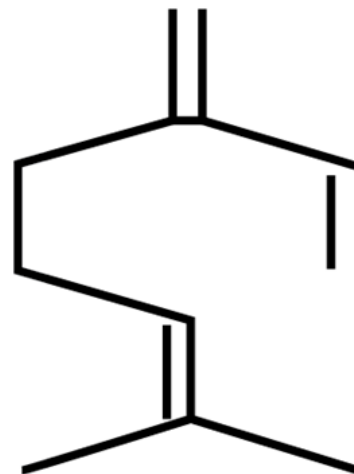
# TERPENES

## TERPENES

- Compounds made of one or more isoprene groups (C<sub>5</sub> H<sub>8</sub>)
- Myrcene most prevalent
- Hop analysis focuses on mono- and sesqui- terpenes
- All terpenes are hydrocarbons, not all hydrocarbons are terpenes
- If it ends in “ene” it doesn’t make the scene

## COMMONLY FOUND TERPENES

- Myrcene – herbal, woody aroma – can be up to 75% of a hops’ total oil, volatile, low solubility
- Farnesene – woody aroma – commonly found in Noble Varieties
- α-humulene – grassy, herbal, woody aroma – highly volatile
- β-pinene – pine-like aroma – less abundant in hops, usually around 1% of total oils, volatile
- β-caryophyllene – woody, cedar-like aroma – contributes to Noble Hop aroma and found in lower levels in newer American Hops, volatile



**MYRCENE**

# SURVIVABLE COMPOUNDS

## 1. MONOTERPENE ALCOHOLS (ex. linalool and geraniol)-

High beer solubility, vital contributors to finished hoppy beer aroma









## 2. SOLUBLE ESTERS (ex. 2MIB and isoamyl isobutyrate) –

Class of compounds that contain a carboxyl functional group between two carbon chains. Aromatically this class of compounds are known to provide tropical, berry, ethereal aromas.

## 3. POLYFUNCTIONAL THIOLS (ex. 3-mercaptohexanol) –

Organosulfur compounds that contain a sulfhydryl group (-SH) along with more than one organic functional groups, often contributing positive beer flavor and aroma. Minute quantities only detectable via specialized lab equipment.

## SURVIVABLE COMPOUNDS

	ISOBUTYL ISOBUTYRATE
	2-NONANONE
	GERANIOL
	LINALOOL
	2-METHYLBUTYL ISOBUTYRATE
	METHYL GERANATE
	ISOAMYL ISOBUTYRATE
	3-MERCAPTOHEXANOL

# SURVIVABLE COMPOUNDS SENSORY EXPERIENCE

- There are labeled fragrance strips in your folder.
- We will come around with the corresponding colored vial of each aroma standard.
- Place the matching fragrance strip in the vial and allow full contact with the liquid. Then remove the strip.
- Wave off excess and allow alcohol dilution to evaporate.
- Smell the fragrance strip.





# **TERPENE**

## **ALCOHOLS**

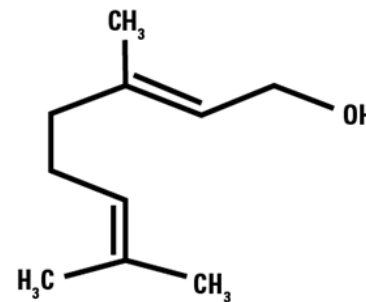


## TERPENE ALCOHOLS

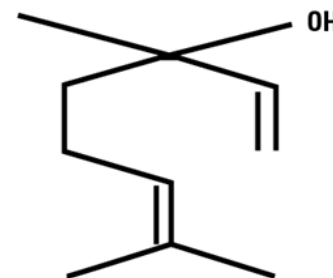
- Closely related to terpenes
- Terpene alcohols are oxygenated
- Alcohols are more soluble due to their greater polarity
- Hops high in terpene alcohols are thought to benefit hot-side additions
- Terpene alcohols are the subject of recent biotransformation research
- **If it ends in “ol” you just might get it all**

## COMMONLY FOUND TERPENE ALCOHOLS

- Geraniol
- Linalool
- Nerol



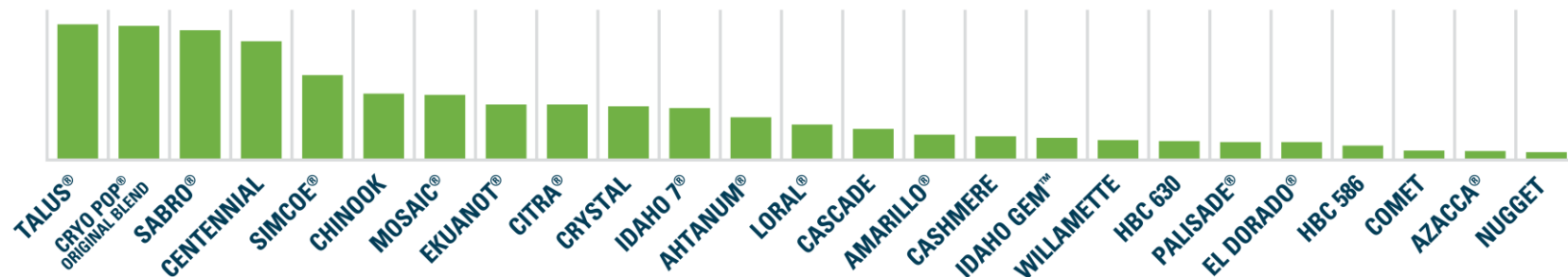
GERANIOL



LINALOOL

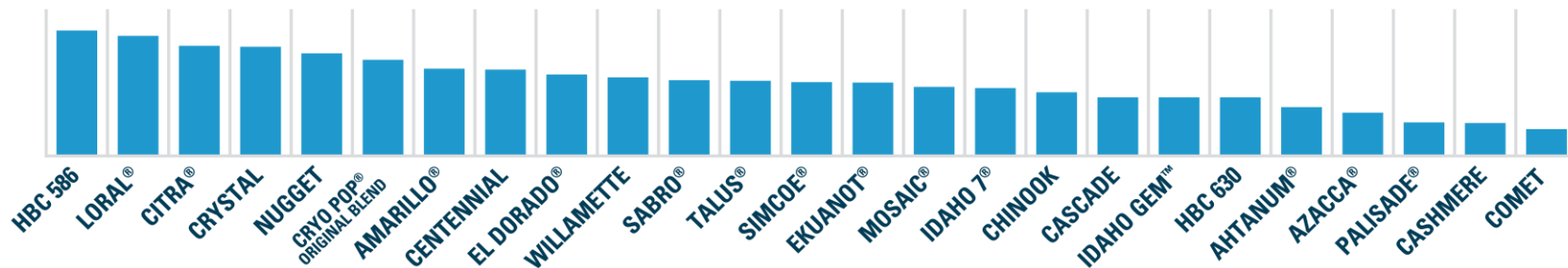
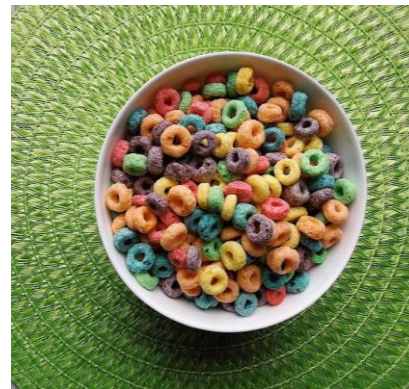
## GERANIOL

- Monoterpene alcohol
- Commonly survives late boil and whirlpool additions
- Geranium-like and citrusy aroma
- Thought to be at least partially biotransformed by certain strains of yeast into  $\beta$ -citronellol during fermentation.



## LINALOOL

- Monoterpene alcohol
- First hop oil discovered in beer
- Commonly survives the brewing process
- High levels act as a 'booster' to increase fruity flavors
- Commonly used as a fragrance and flavoring in cosmetics and candy.
- Strong fruity and floral aroma, similar to the aroma of Froot Loops™ cereal





# **ESTERS & KETONES**



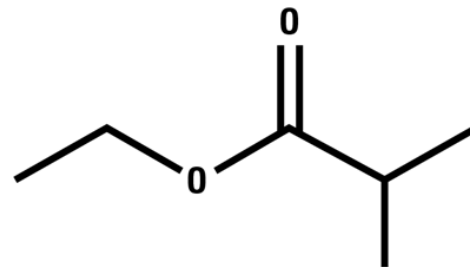


## ESTERS AND KETONES

- 3rd most abundant class of essential oil compounds ~ 15%
- Found in the Bracteoles of hop cone
- Esters typically provide fruity notes
- **If it ends in “ate” it probably tastes great**

## COMMONLY FOUND ESTERS AND KETONES

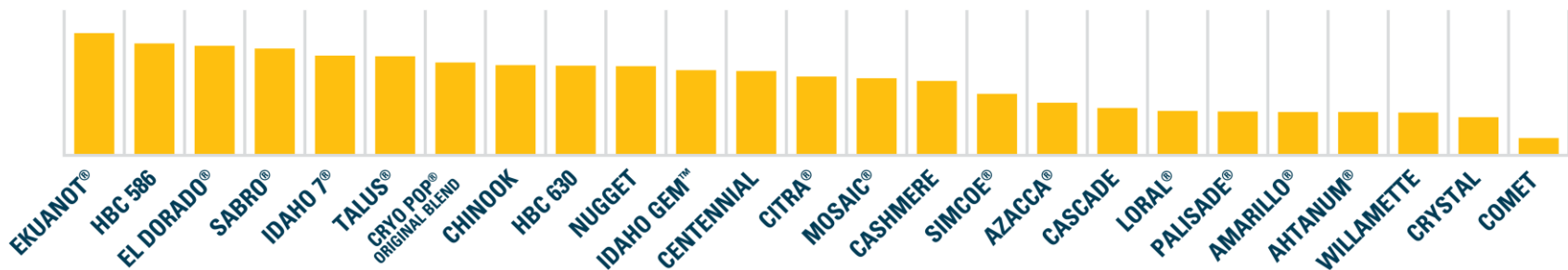
- 2-methylbutyl isobutyrate
- Methyl geranate
- 2-nonanone
- Butanoic acid 3-methylbutyl ester



**ETHYL ISOBUTYRATE**

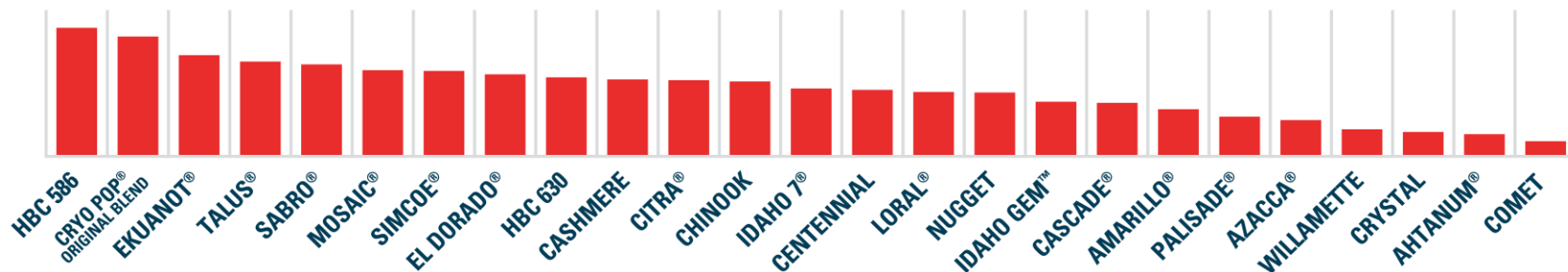
## 2-METHYLBUTYL ISOBUTYRATE

- Ester derived from hops
- Typically survives the brewing process
- Fruity aroma, specifically apricot



## ISOAMYL ISOBUTYRATE

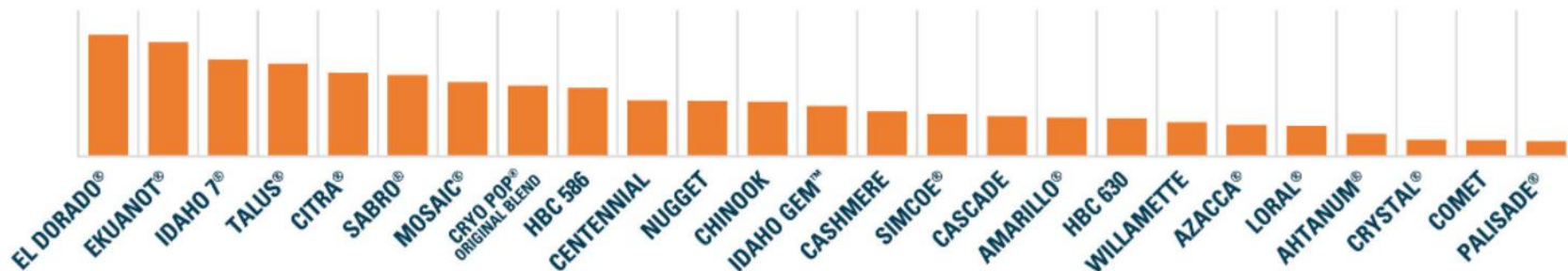
- Hop-derived ester
- Typically survives the brewing process
- Fruity and tropical fruit aromas





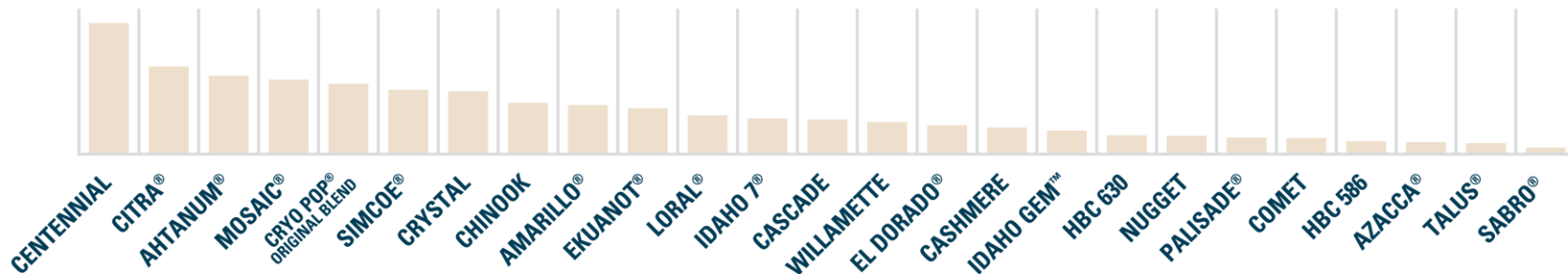
## ISOBUTYL ISOBUTYRATE

- Hop-derived ester
- Typically survives the brewing process
- Fruity and pineapple aromas



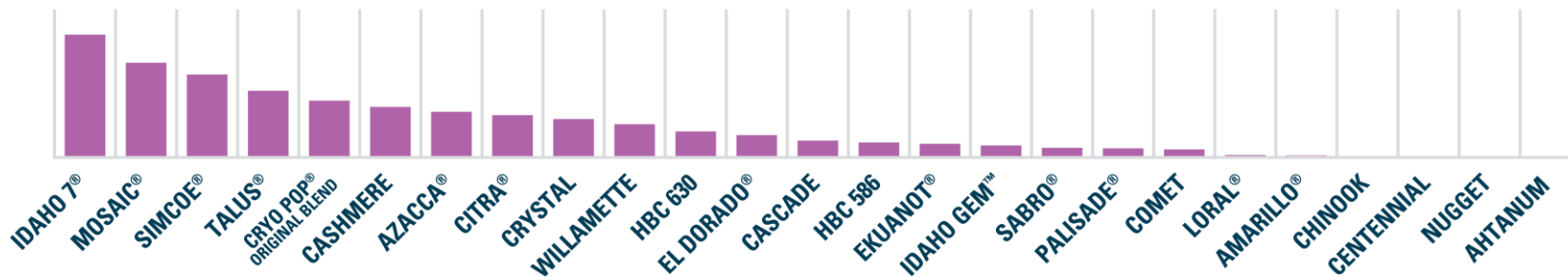
## METHYL GERANATE

- Methyl ester
- Derived from hops
- Typically survives the brewing process
- Fruity and floral aroma



## 2-NONANONE

- Ketone
- Variety of different aromas
- Can be sweet and fruity
- Can be cheesy, buttery, and waxy



# **SULFUR-CONTAINING COMPOUNDS**





## SULFUR COMPOUNDS

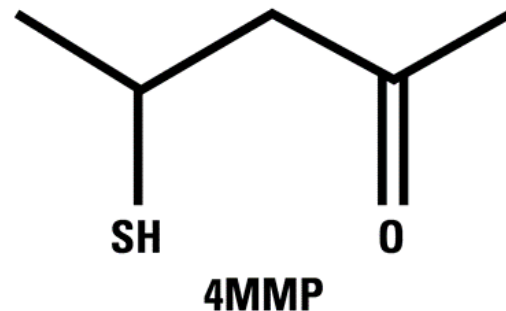
- Represent an increasingly important area of study in hop aroma science
- Difficult to detect using a traditional GC-MS
- Usually found in extremely small concentrations in hops
- Human nose is excellent at detecting sulfur compounds
- Common confusion surrounds the prefixes mercapto and sulfanyl

## POLYFUNCTIONAL THIOL

- Blanket term for an organic compound containing a sulfhydryl functional group(-SH)
- Often contributing positive beer flavor and aroma

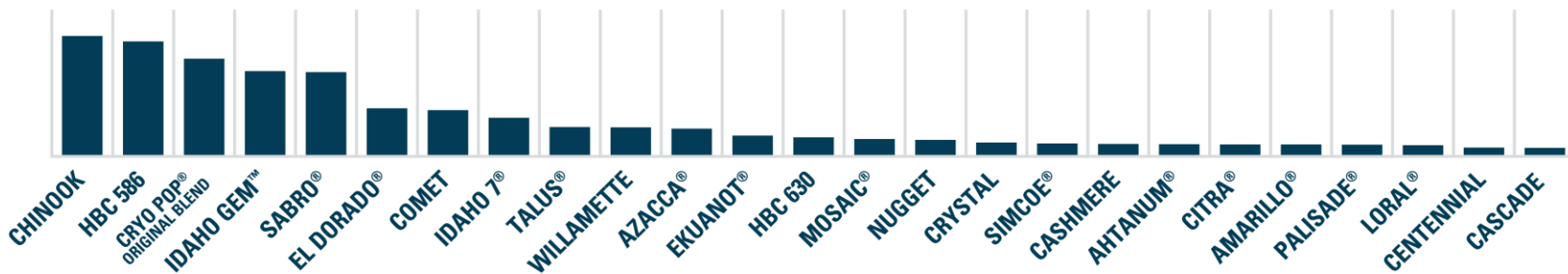
## COMMONLY FOUND SULFUR COMPOUNDS

- 4-methyl-4-sulfanylpentan-2-one (4MSP or 4MMP)
- 3-sulfanylhexas-1-ol (3SH or 3MH)
- 3-sulfanylhexas-1-yl acetate (3SHA or 3MHA)
- 3-sulfanyl-4-methylpentyl acetate (3S4MPA or 3M4MPA)
- 3-sulfanyl-4-methylpentan-1-ol (3S4MP or 3M4MP)



### 3-MERCAPTOHEXANOL

- Polyfunctional thiol
- Commonly found in hops
- Tropical and grapefruit aroma
- Can be converted by yeast into 3SHA (3MHA)



**THE SURVIVABLES**

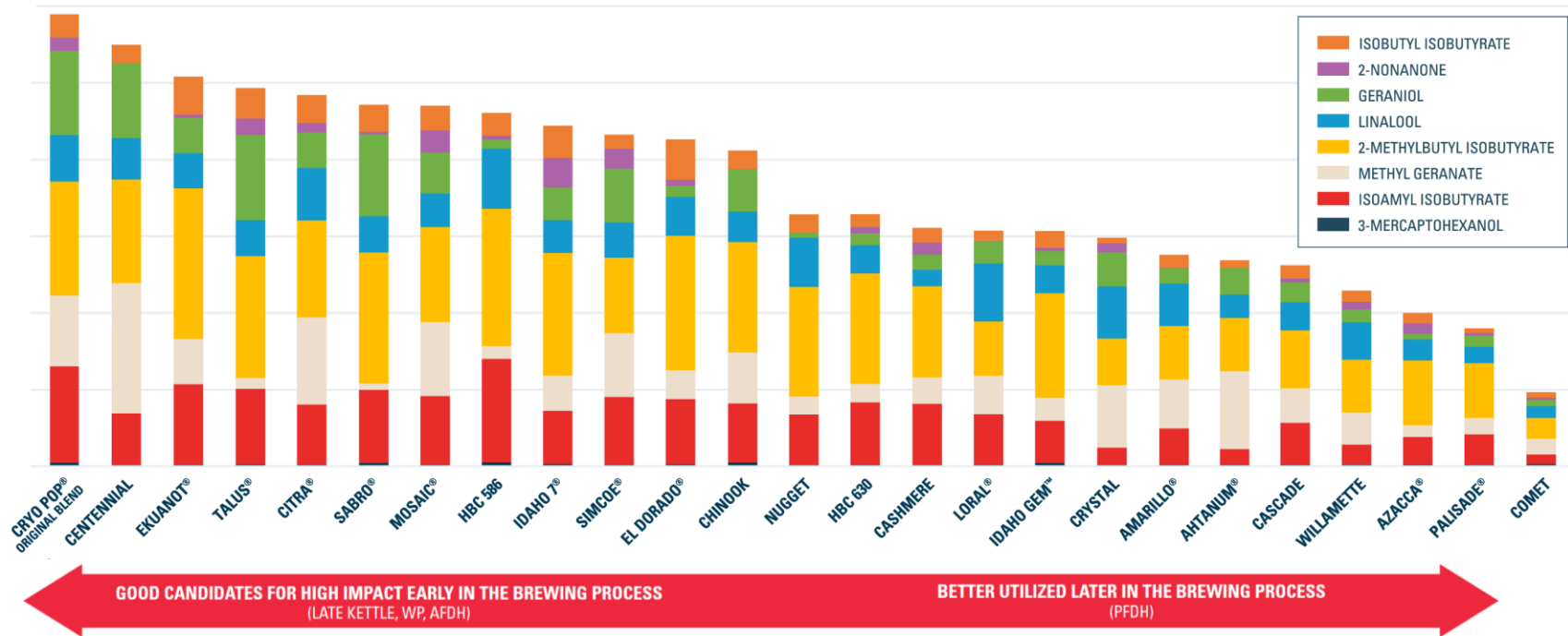
# GRAPH



## Crop Year 2021

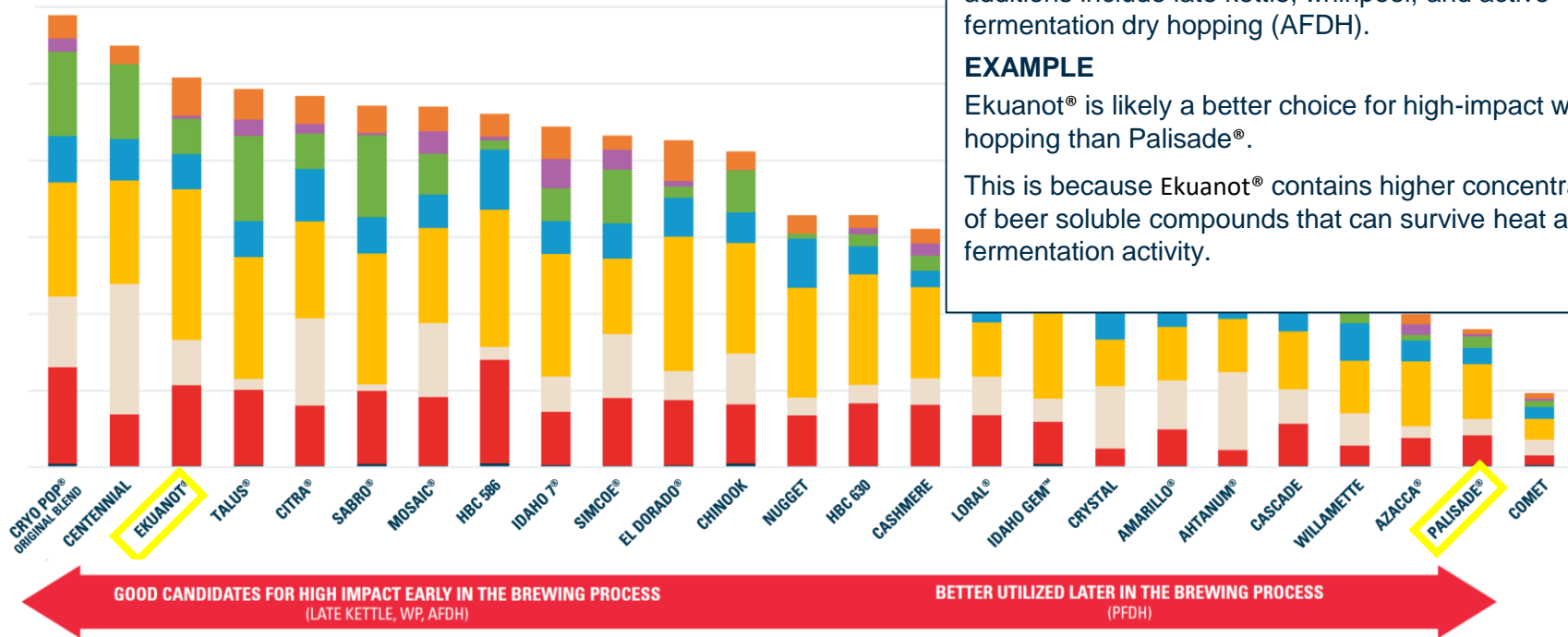
### ANSWERS SUCH QUESTIONS AS:

- What variety should I use?
- Where in the process should I use it?
- Which hops work together in combination?
- How can I use a variety to its maximum effect?





## Crop Year 2021



### 1. USE HIGH SURVIVABLES HOPS EARLY (OR LATE)

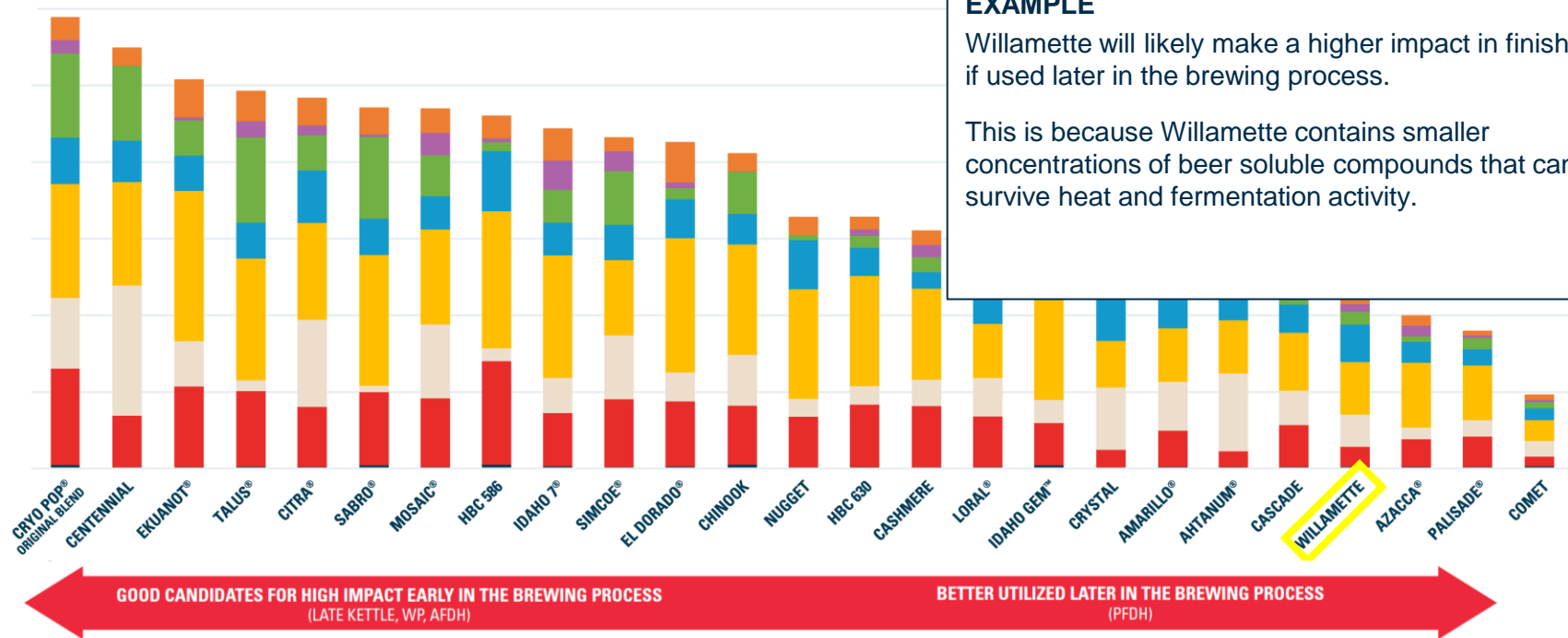
Hops with higher concentrations of survivable compounds have a better likelihood of being successful when used earlier in the brewing process than hops with low concentrations of these same compounds. Early additions include late kettle, whirlpool, and active fermentation dry hopping (AFDH).

#### EXAMPLE

Ekuanot® is likely a better choice for high-impact whirlpool hopping than Palisade®.

This is because Ekuanot® contains higher concentrations of beer soluble compounds that can survive heat and fermentation activity.

## Crop Year 2021



## 2. USE LOW SURVIVABLES HOPS LATE

Similarly, we can say that hops with lower concentrations are likely to find better success and a more positive impact in beer when used later in the process, such as post fermentation dry hopping (PFDH).

### EXAMPLE

Willamette will likely make a higher impact in finished beer if used later in the brewing process.

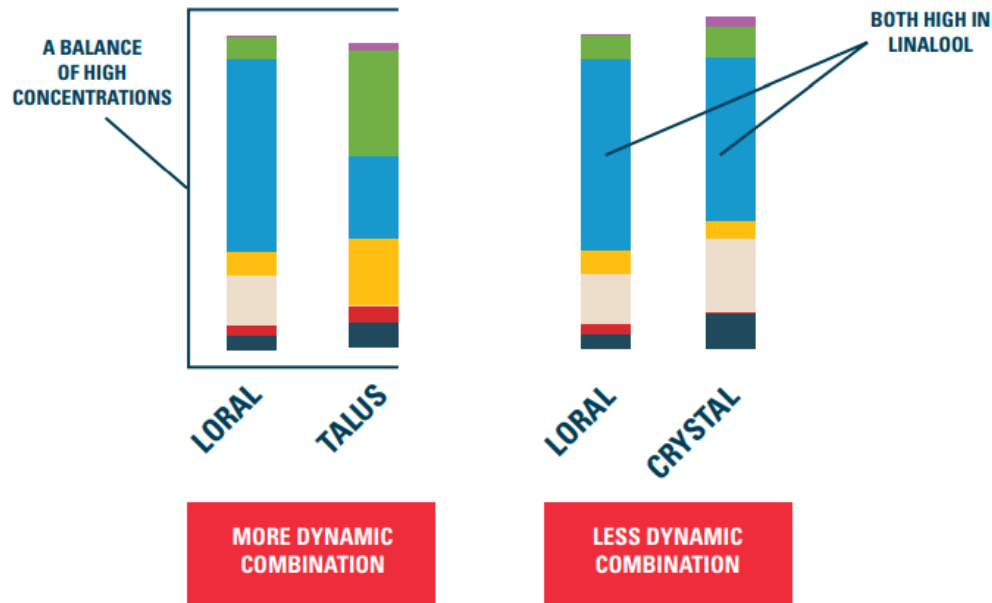
This is because Willamette contains smaller concentrations of beer soluble compounds that can survive heat and fermentation activity.

### 3. BLEND HOPS TO MAXIMIZE BENEFICIAL CONCENTRATIONS

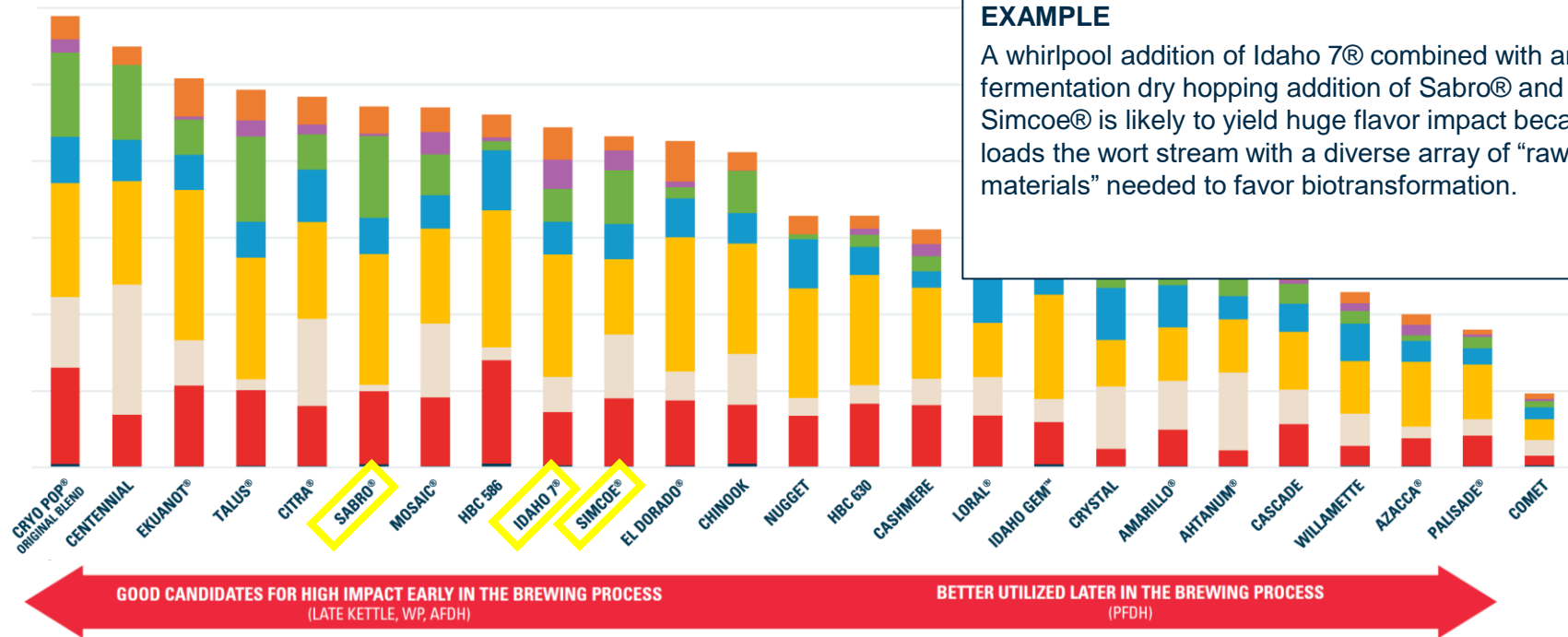
Focus on balancing high concentrations when creating blends.

#### EXAMPLE

Because Loral® is high in linalool and Talus™ is high in geraniol, the two of them are likely to work well in concert. Loral® and Crystal are both high in linalool and would therefore likely create a less dynamic and more one-dimensional blend.



## Crop Year 2021



### 4. LOAD WORT STREAMS WITH SURVIVABLES EARLY

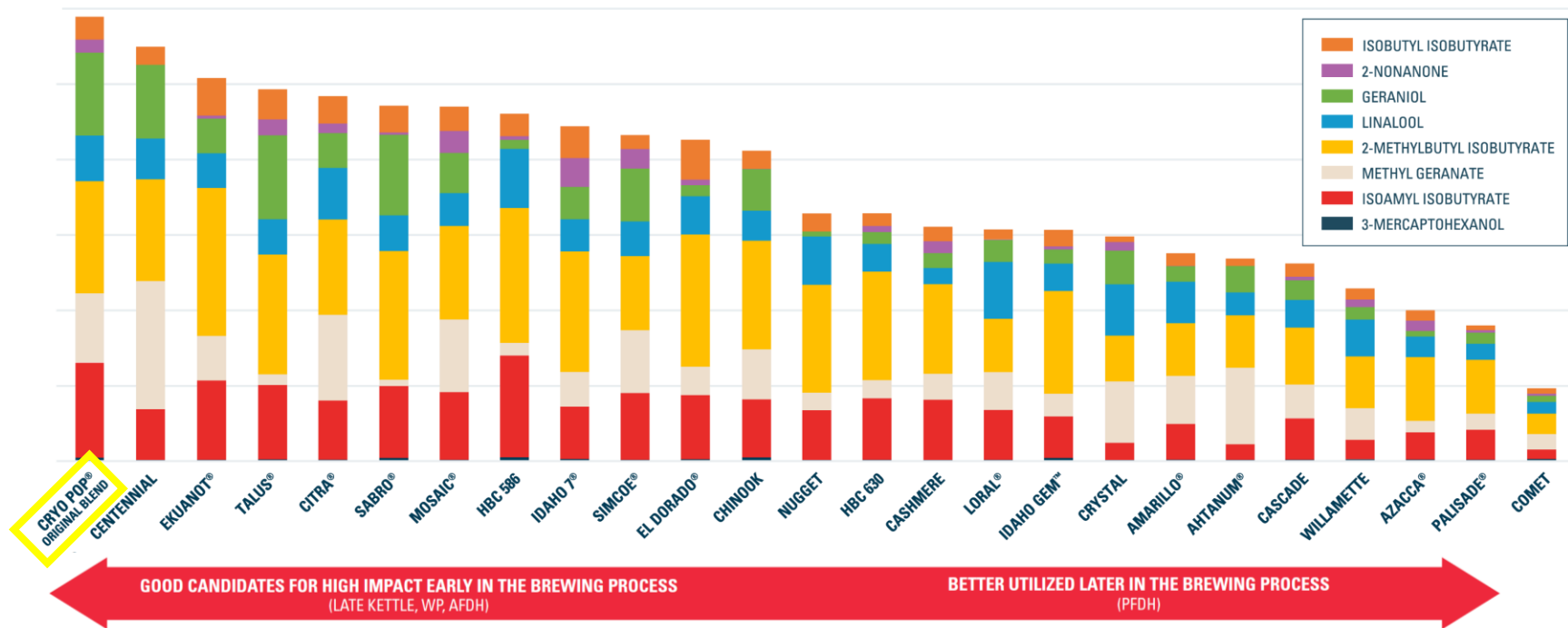
High concentrations of survivables in whirlpool and active fermentation dry hopping can create conditions necessary for beneficial biotransformation.

#### EXAMPLE

A whirlpool addition of Idaho 7® combined with an active fermentation dry hopping addition of Sabro® and Simcoe® is likely to yield huge flavor impact because it loads the wort stream with a diverse array of “raw materials” needed to favor biotransformation.

# CRYO POP® ORIGINAL BLEND

Crop Year 2021





# HOP & BEER SENSORY LEXICON



## AROMA



### DRIED FRUIT

Date • Dried Apricot  
Dried Fig • Raisin



### BERRY

Black Currant • Blueberry  
Grape • Raspberry • Strawberry



### STONE FRUIT

Apricot • Cherry  
Peach • Plum



### POMME

Apple • Pear



### MELON

Cantaloupe • Cucumber  
Honeydew • Watermelon



### TROPICAL

Banana • Coconut • Guava • Lychee  
Mango • Passion Fruit • Pineapple



### CITRUS

Grapefruit • Lemon  
Lemongrass • Lime • Orange



### FLORAL

Cherry Blossom • Geranium  
Jasmine • Rose • Soapy



### HERBAL

Black Tea • Dill • Green Tea  
Mint • Rosemary • Thyme



### VEGETAL

Cabbage • Celery  
Green Pepper • Tomato Plant



### GRASSY

Green Grass • Hay



### EARTHY

Barnyard • Compost • Geosmin  
Leather • Mushroom • Soil



### WOODY

Cedar • Pine • Resinous • Sawdust  
Tea Tree • Tobacco



### SPICY

Anise • Black Pepper  
Cinnamon • Clove • Ginger



### SWEET AROMATIC

Bubblegum • Caramel • Chocolate  
Creamy • Honey • Vanilla



### ONION / GARLIC

Garlic • Green Onion • Onion



### DANK

Cannabis • Skunk



### NUTTY

Almond • Peanut • Walnut



### BREADY

Biscuit • Dough  
Graham Cracker • Oatmeal • Rye



### ROASTED

Coffee • Dark Malt



### OFF-NOTES

Burnt Rubber • Cardboard • Catty  
Cheesy • Diesel • Musty • Plastic/Waxy  
Smoky • Sulfur • Sweaty

\* Acetaldehyde • Butyric Acid  
Diacetyl • DMS • Lactic Acid  
Light Strike • Metallic

\*Off notes occurring in beer

## TASTE

BITTER SALT SOUR SWEET UMAMI

## MOUTHFEEL

ALCOHOL ASTRINGENCY BODY CARBONATION  
Warming • Boozy Drying • Grippy Thickness • Fullness Bubble Size • Density

Handbook pages 20-21

# CRYO POP® ORIGINAL BLEND

## CONVENTIONAL USAGE

- Brewer looking for a “go-to” solution for all juicy, hazy, fruit-forward beers
- Brewer needing a user-friendly solution to help them make market-relevant beer

## STRATEGIC USAGE

- Brewer focused on maximizing contributions from individual hop compounds
- Brewer desiring to bridge the gap between raw hop and finished beer aromas



YCH058

# SUPERCHARGED IPA

**TASTING NOTES: MANGO • PEACH • APRICOT  
ORANGE • LIME • BANANA • BUBBLEGUM**



## SPECIFICATIONS

ORIGINAL GRAVITY	FINAL GRAVITY	IBU	ABV
1.059	1.011	43	6.2%

## INGREDIENTS

GRAINS	AMOUNT
Pale 2-Row Malt .....	86%
White Wheat .....	12%
Acidulated Malt .....	2%

YEAST & ADJUNCTS	AMOUNT
Kaiser .....	14 million cells/mL
Whirlfloc .....	Variable
Yeast Nutrient .....	Variable

HOPS	TYPE	AA%	ADDITION	AMOUNT
Simcoe® Brand .....	CO2 Hop Extract.....	59.0%	60 Min.....	0.25 g/L
Simcoe® Brand .....	Cryo Hops® Pellets.....	23.0%	Flameout .....	1.5 g/L

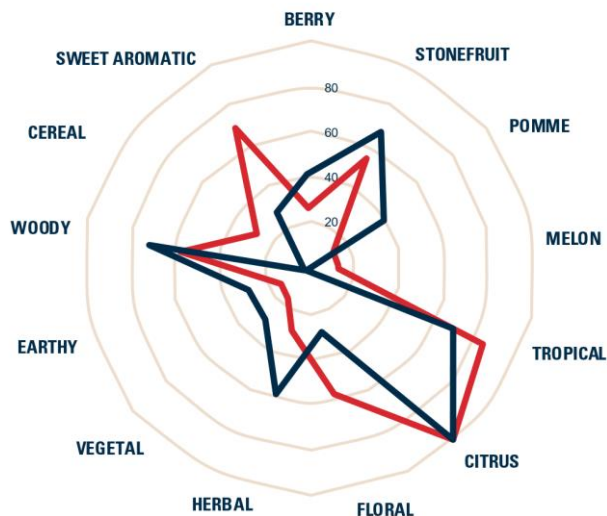
Cryo Pop®  
Original Blend .....

Cryo Hops® Pellets.....	20.0%	Dry Hop .....	7.0 g/L
-------------------------	-------	---------------	---------

## INSTRUCTIONS

- STEP 1** Perform a single infusion mash at 153°F/67°C, Mash rest for 30 min.
- STEP 2** Vorlauf until the wort has cleared and is free of grain particles.
- STEP 3** Runoff into the kettle and sparge with 170°F/77°C water.
- STEP 4** Bring the wort to a boil. Add hops according to schedule.
- STEP 5** With 15 min left for the boil, add Whirlfloc and yeast nutrient.
- STEP 6** After 60 min, turn off the burner. Note: All whirlpool additions are calculated based on a 15-minute whirlpool.
- STEP 7** Gently create a whirlpool in the kettle. Add the whirlpool hop additions.
- STEP 8** Quickly cool the wort to 68°F/20°C, aerate with 10 ppm O2, and transfer into a sanitized fermenter.
- STEP 9** Pitch the yeast and add a blowoff tube to the fermenter.
- STEP 10** When beer is at 85% attenuation, add Dry Hops per Recipe, raise tank temp to 72°F/22°C.
- STEP 11** Add Spunding valve to tank and set to 8psi.
- STEP 12** After 2 days, dump trub and spent hops from bottom of tank.
- STEP 13** After beer has passed forced diacetyl test, cool the fermenter to 32°F/0°C.
- STEP 14** Force carbonate to 2.55.

# CRYO POP® ORIGINAL BLEND



**Cryo Pop®  
Original Blend  
Active**

**Cryo Pop®  
Original Blend  
Post**

## BEER SENSORY ANALYSIS

### Active Fermentation

Peach, Pineapple, Strawberry (50% each)  
Guava, Mango, Orange (38% each)

### Post Fermentation

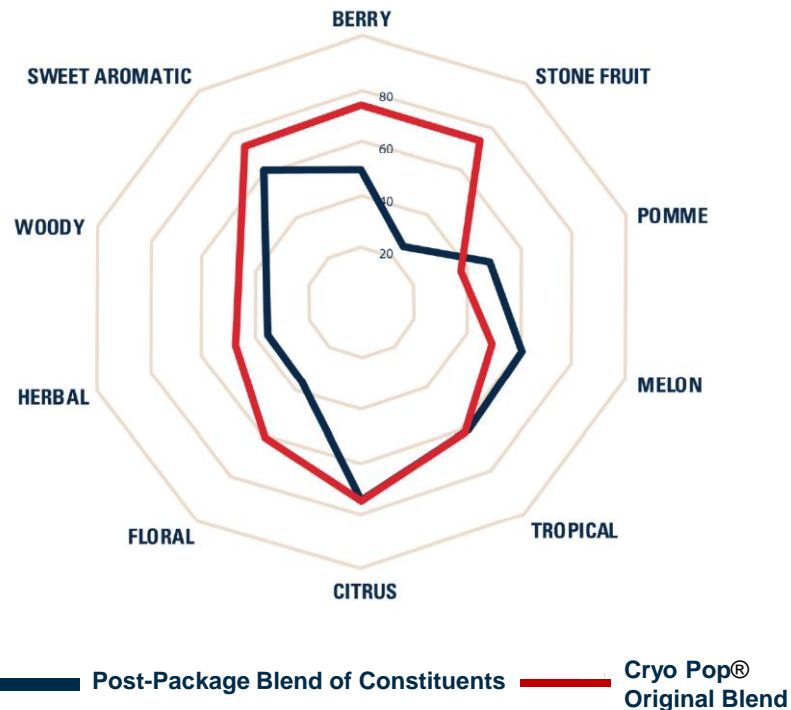
Peach, Grapefruit (50% each)  
Mango, Pineapple, Pine, Sweetgrass (38% each)



# CRYO POP® ORIGINAL BLEND

## BEER SENSORY ANALYSIS

- Trial designed to test the impact of synergies between components
- Cryo Pop® Original Blend showed significantly higher incidence of desirable aromas in Berry, Stone Fruit, Floral, and Sweet Aromatic
- Superior performance is believed to be created by synergies between beer-soluble components





# QUESTIONS?

**YCH Technical Brewing Team Contact**  
**[brewinghelp@yakimachief.com](mailto:brewinghelp@yakimachief.com)**

**• AMERICAN HOPS. •**  
**FROM THE**  
**PACIFIC NORTHWEST™**

---

---