YAKIMA CHIEF HOPS

SURVIVABLE COMPOUNDS

A BREWER'S HANDBOOK

PRESENTERS

Patrick Jensen has been with YCH for more than three years. He was born in Yakima, Washington and knew nothing of hops and beer until he graduated from Central Washington University with a B.S. in chemistry in 2004. He owned a Thai restaurant where he was the head chef, but soon after graduation ended up in the hop industry. He has managed several hop quality laboratories since, and now manages the research and development laboratory for YCH. He works to develop analytical methods for hop and brewing research and provides technical expertise to our growers, production processes, quality control and sales team. Pat believes all beer is great, because…can you believe brewers pay me to do what I love? He lives in Yakima, Washington with his wife, daughter and twin autistic sons.

Spencer Tielkemeier is the East Division and Brewing Innovations Lead 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 Hops, 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, and dog.

Tessa Schilaty is a Seattleite who brewed beer in Sweden, Germany, Chile, and Scotland before graduating from Heriot-Watt University with an MSc in Brewing and Distilling. She is now helping to further develop the YCH sensory program with a special emphasis on beer sensory. Tessa coordinates with Yakima Chief Hops' sensory team and brewing partners to design, execute, and report on experiments which help further our collective understanding of hops and beer flavor. When trying to explain her job to strangers at a dinner party, Tessa describes what she does as "Drinking beer, but for science".

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.

Pages 2-3

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

Pages 4-7

HOP OIL COMPONENTS

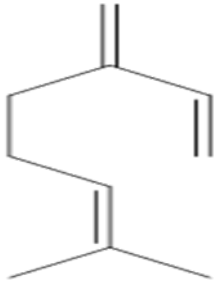
OVER 1,000 DIFFERENT COMPOUNDS

- 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 (C5 H8)
- 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



myrcene

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

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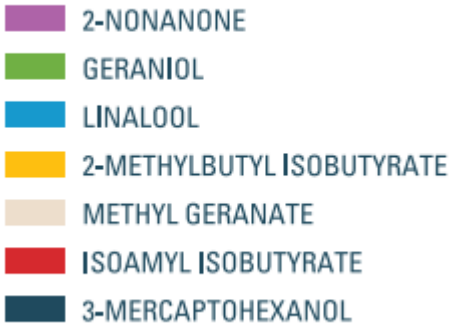
SURVIVABLE COMPOUNDS

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.



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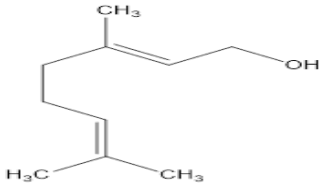
TERPENE ALCOHOLS

TERPENE ALCOHOLS

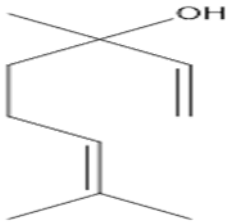
- Closely related to terpenes
- Terpene alcohols are oxygenated
- Alcohols are more soluble due to their greater polarity
- Hops high in terpene alcohols are thought to benefit hot-side additions
- Terpene alcohols are the subject of recent biotransformation research
- If it ends in “ol” you just might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

COMMONLY FOUND TERPENE ALCOHOLS

- Geraniol
- Linalool
- Nerol



Geraniol



Linalool

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TERPENE ALCOHOLS

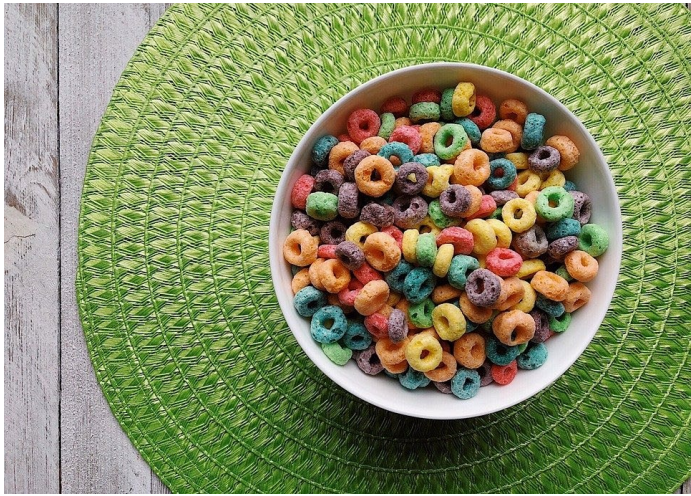
GERANIOL

- 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 β-citronellol during fermentation.

TERPENE ALCOHOLS

LINALOOL

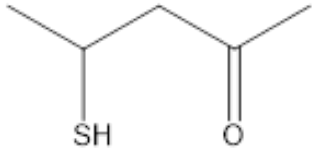
- Monoterpene alcohol
- First hop oil discovered in beer
- Commonly survives the brewing process
- High levels act as a ‘booster’ to increase fruity flavors
- Commonly used as a fragrance and flavoring in cosmetics and candy.
- Strong fruity and floral aroma, similar to the aroma of Froot Loops™ cereal



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

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SULFUR-CONTAINING COMPOUNDS

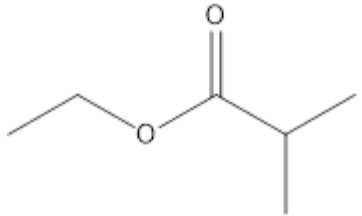
3-MERCAPTOHEXANOL

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

ESTERS AND 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

ESTERS AND KETONES

2-METHYLBUTYL ISOBUTYRATE

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

ESTERS AND KETONES

ISOAMYL ISOBUTYRATE

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

ESTERS AND KETONES

METHYL GERANATE

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

ESTERS AND KETONES

2-NONANONE

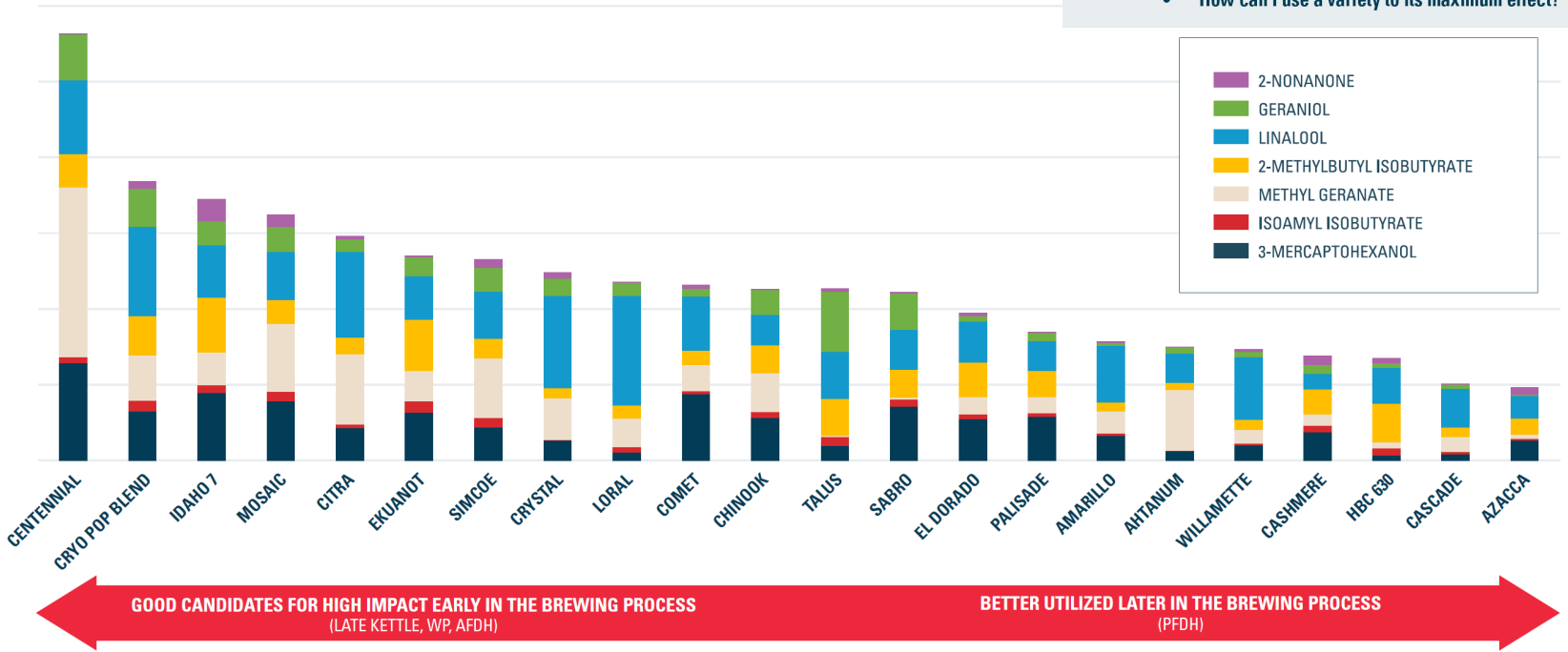
- Ketone
- Variety of different aromas
- Can be sweet and fruity
- Can be cheesy, buttery, and waxy

SURVIVABLE COMPOUNDS

THE SURVIVABLES GRAPH

ANSWERS SUCH QUESTIONS AS:

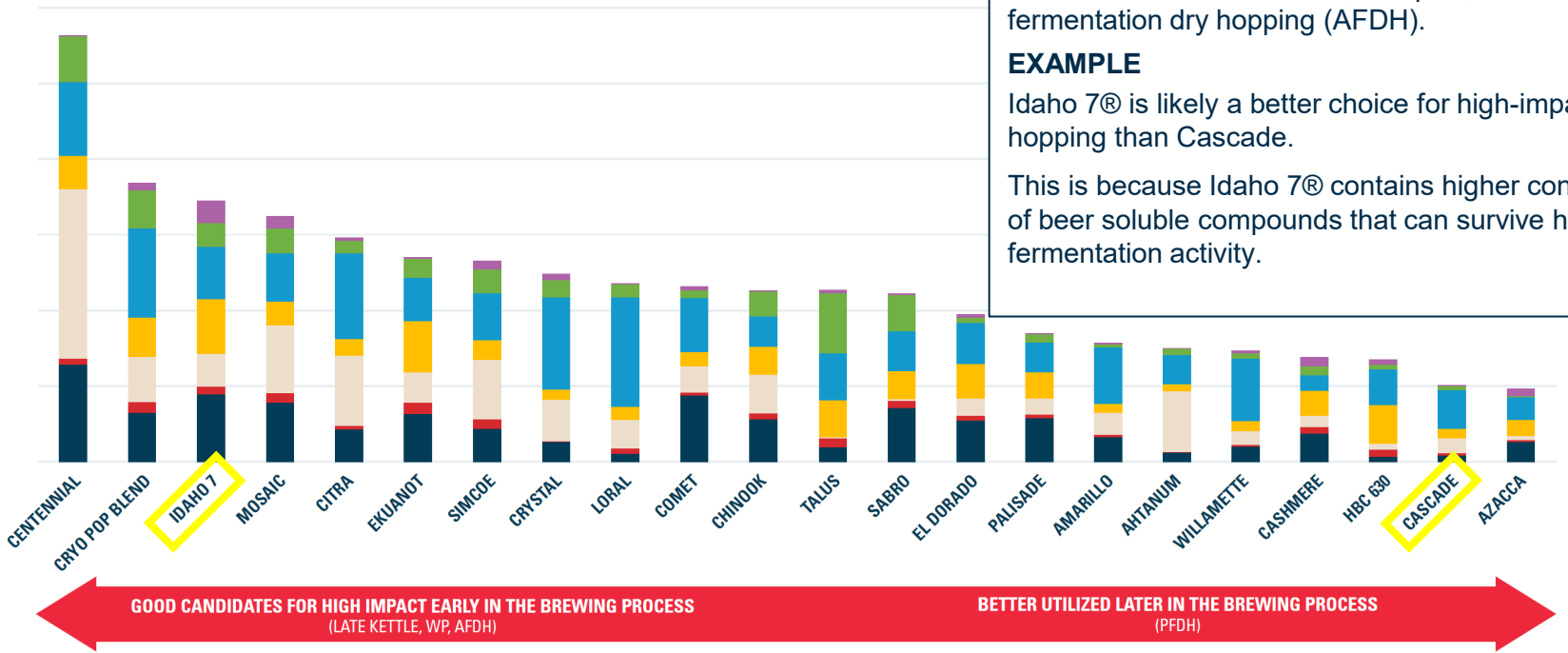
- What variety should I use?
- Where in the process should I use it?
- Which hops work together in combination?
- How can I use a variety to its maximum effect?



Pages 8-9

SURVIVABLE COMPOUNDS

THE SURVIVABLES GRAPH



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

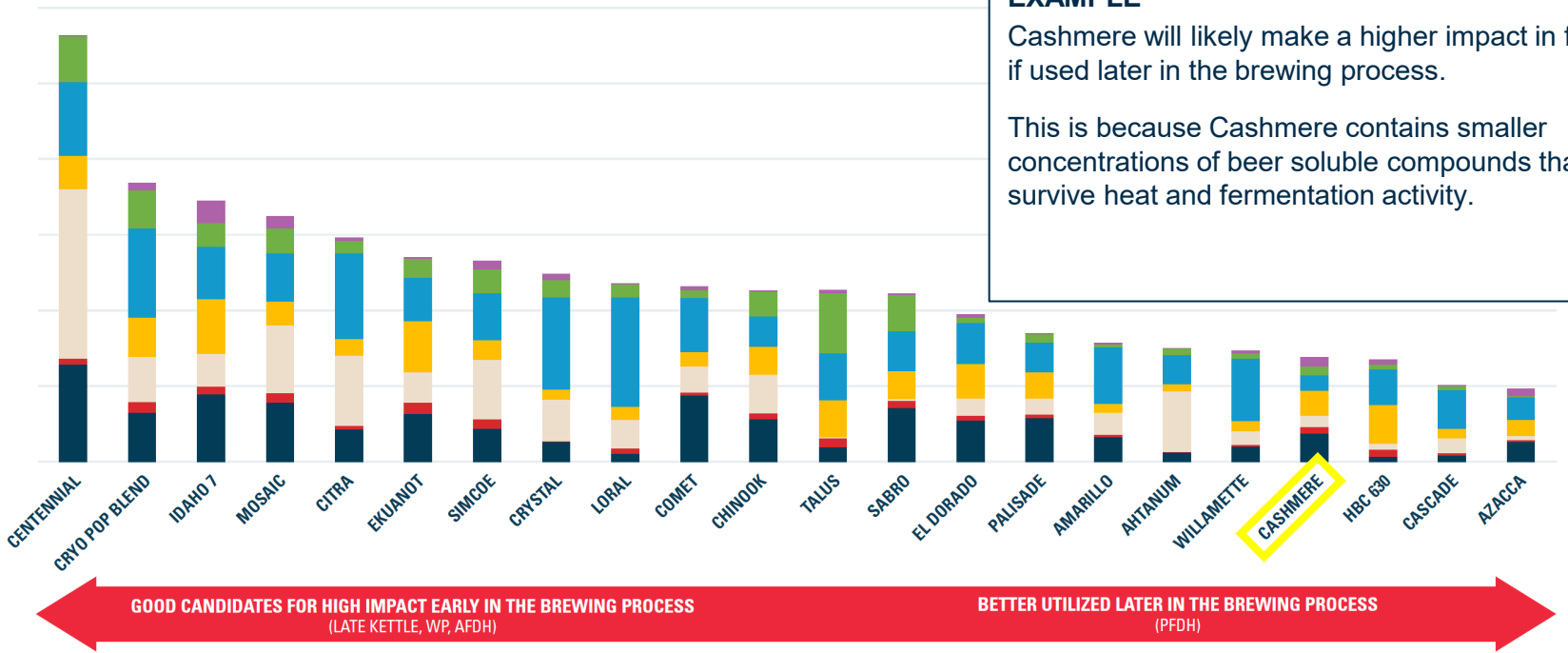
Idaho 7® is likely a better choice for high-impact whirlpool hopping than Cascade.

This is because Idaho 7® contains higher concentrations of beer soluble compounds that can survive heat and fermentation activity.

Pages 8-9

SURVIVABLE COMPOUNDS

THE SURVIVABLES GRAPH



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

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

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

Pages 8-9

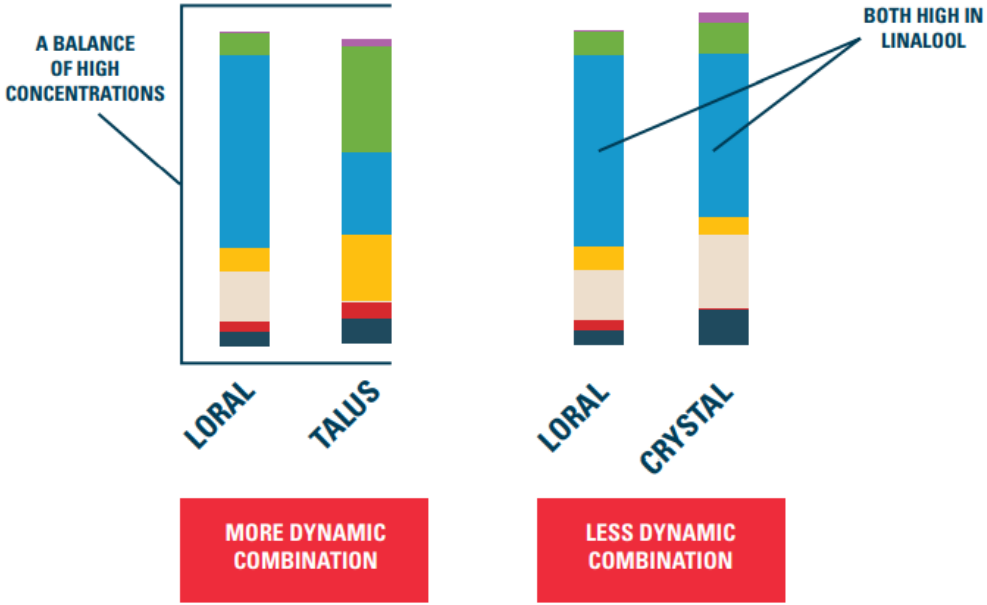
SURVIVABLE COMPOUNDS

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.



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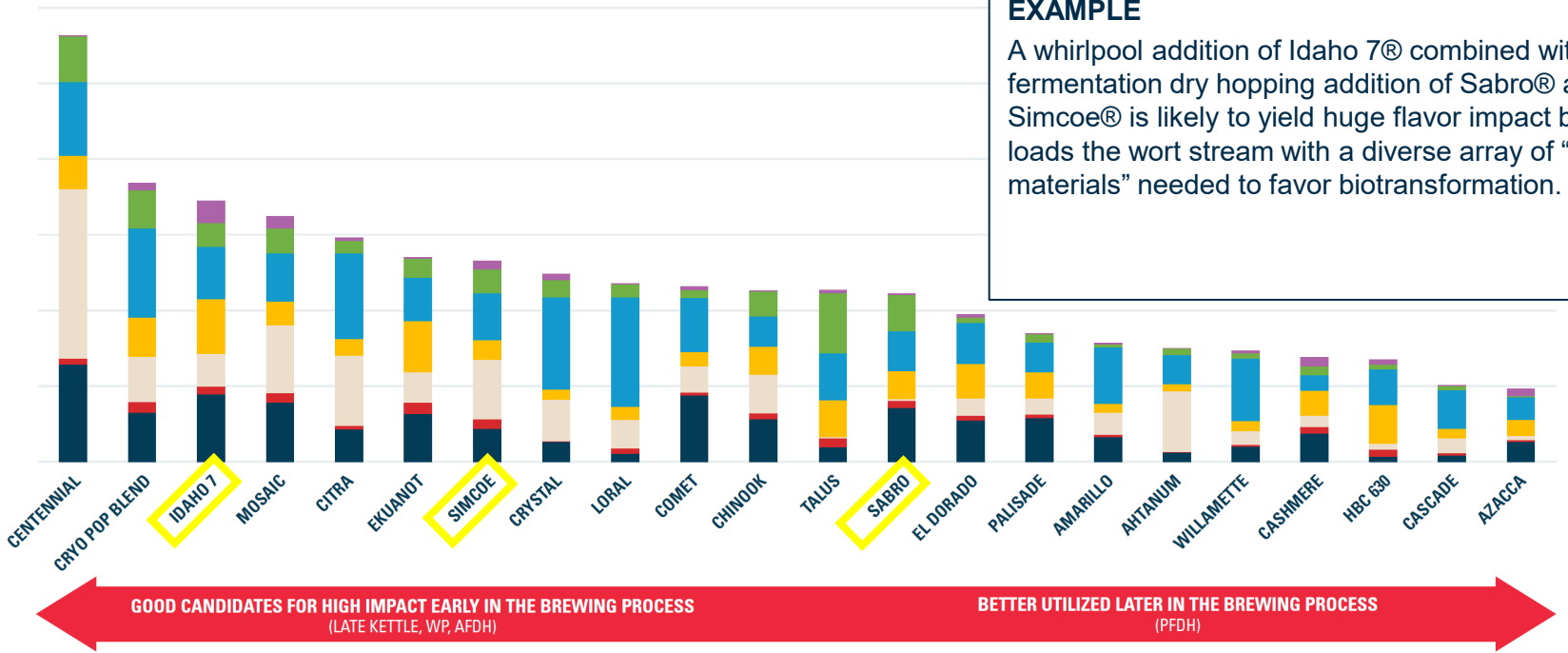
SURVIVABLE COMPOUNDS

THE SURVIVABLES GRAPH



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.

Pages 8-10

CRYO POP™ ORIGINAL BLEND

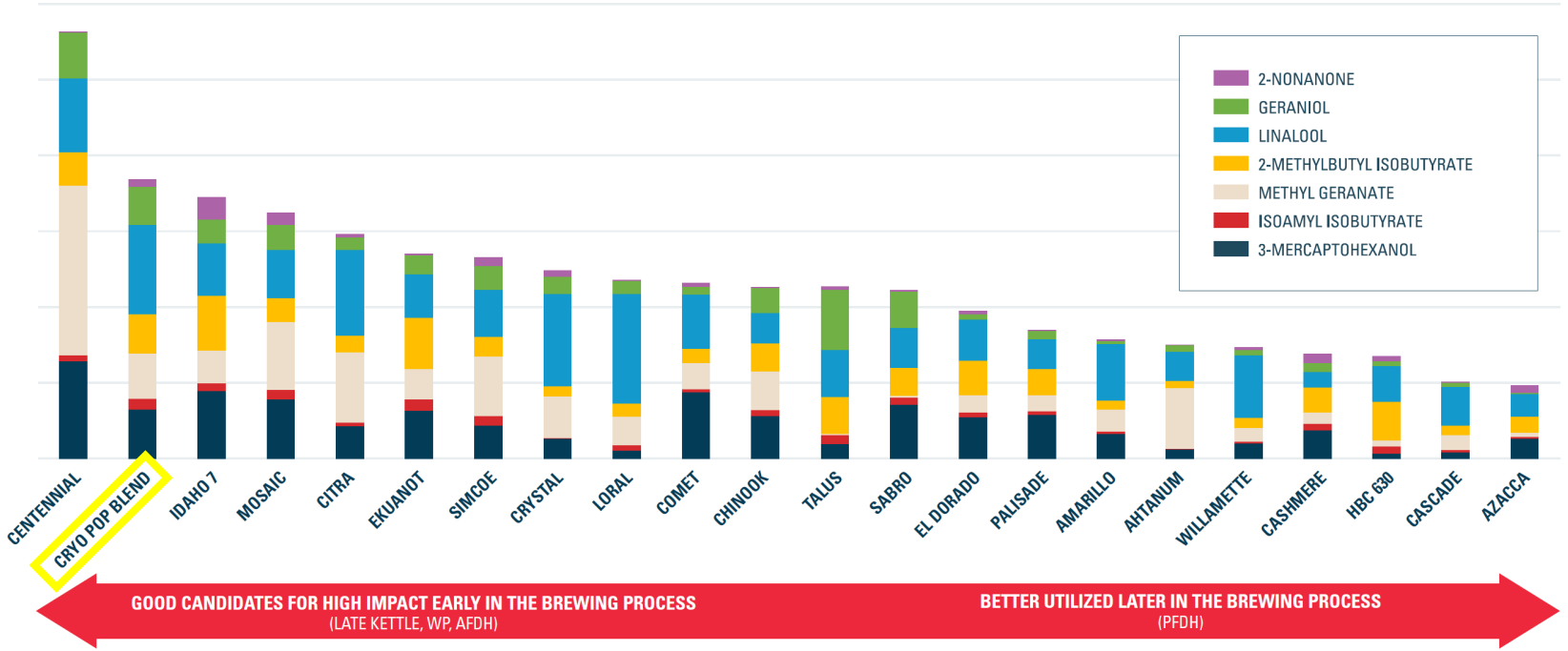
BORN OF BEER SOLUBLE HOP COMPOUND RESEARCH

Supercharged pellet that provides brewers with a dynamic solution for juicy, fruit-forward, highly aromatic applications, showing massive **tropical, stone fruit, and citrus aromas**

Maximizing concentrations of the most impactful and complementary hop compounds, we offer an incredibly powerful hop pellet that creates a true ‘pop’ of aromas in beers

CRYO POP™ ORIGINAL BLEND

THE SURVIVABLES GRAPH



Pages 8-9

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

Pages 14-19

ALL-GRAIN RECIPE

YCH037

CRYO POP™ ORIGINAL BLEND NEIPA

TASTING NOTES: MANGO • RUBY RED GRAPEFRUIT • PEACH • FLORAL

SPECIFICATIONS

ORIGINAL GRAVITY	FINAL GRAVITY	IBU	ABV
1.065	1.016	25	6.5%

INGREDIENTS

GRAINS	AMOUNT
2-Row or Pilsner Malt	60%
White Wheat	25%
Flaked Oats	15%

YEAST & ADJUNCTS	AMOUNT
London III	16 million cells/mL
Whirlfloc	Variable
Yeast Nutrient	Variable

HOPS	TYPE	AA%	ADDITION	AMOUNT
Cryo Pop™ Original Blend	Cryo Hops® Pellets	18.5%	Flame Out	1.9 g/L
Cryo Pop™ Original Blend	Cryo Hops® Pellets	18.5%	Dry Hop 1	5.8 g/L
Cryo Pop™ Original Blend	Cryo Hops® Pellets	18.5%	Dry Hop 2	1.9 g/L

INSTRUCTIONS

STEP 1 Perform an infusion mash to achieve a mash temp of 154°F/68°C for 60 min.

STEP 2 Vorlauf until the wort has cleared and is free of grain particles.

STEP 3 Runoff into the kettle and sparge with 180°F/82°C water.

STEP 4 Bring the wort to a boil.

STEP 5 After 45 min, add Whirlfloc for clarity and yeast nutrient for yeast health.

STEP 6 After 60 min, turn off the burner. Let the wort cool to about 204°F/96°C. Add the whirlpool hop additions.
Note: All whirlpool additions are calculated based on a 15 minute whirlpool starting at 204°F/96°C.

STEP 7 Gently create a whirlpool in the kettle.

STEP 8 Quickly cool the wort to 64°F/18°C, aerate it, and transfer in into a sanitized fermenter.

STEP 9 Pitch the appropriate amount of yeast and add either an airlock or blowoff tube to the fermenter.

STEP 10 Dry Hop 1: Add hops at middle of active fermentation, with approximately 1.024 – 1.032 specific gravity left before final gravity.

STEP 11 Dry Hop 2: After final gravity is hit dry hop for two days at 72° F/ 22° C, rousing once at 24 hours with C02. Dump hops from bottom of FV after 48 hours

STEP 12 Elevated hopping rates tend to produce hop creep often resulting in diacetyl production. After beer passes forced diacetyl test, drop temperature to 32° F/ 0° C.

ALL-GRAIN RECIPE

YCH038

CRYO POP™ ORIGINAL BLEND AMPLIFIER WEST COAST IPA

TASTING NOTES: PINEAPPLE • STONE FRUIT • PEACH • GRAPEFRUIT • PINE • CEDAR

SPECIFICATIONS

ORIGINAL GRAVITY	FINAL GRAVITY	IBU	ABV
1.059	1.010	58	6.2%

INGREDIENTS

GRAINS

	AMOUNT
2-Row or Pilsner Malt	85%
Malted Wheat	5%
Crystal 60 Malt	5%
Acidulated Malt	As Needed

YEAST & ADJUNCTS

English Ale Yeast	14.5 million cells/mL
Whirlfloc	Variable
Yeast Nutrient	Variable

HOPS

	TYPE	AA%	ADDITION	AMOUNT
Warrior® Brand	T-90 Pellets	16.0%	60 min	0.5 g/L
Talus® Brand	T-90 Pellets	9.0%	Whirlpool	3.9 g/L
Cryo Pop™ Original Blend	Cryo Hops® Pellets		Dry Hop 1	1.0 g/L
Simcoe® Brand	T-90 Pellets		Dry Hop 1	3.9 g/L
Cryo Pop™ Original Blend	Cryo Hops® Pellets		Dry Hop 2	1.0 g/L
Citra® Brand	Cryo Hops® Pellets		Dry Hop 2	1.0 g/L
Mosaic® Brand	T-90 Pellets		Dry Hop 2	2.0 g/L

INSTRUCTIONS

STEP 1 Perform an infusion mash to achieve a mash temp of 152°F/67°C for 60 min.

STEP 2 Vorlauf until the wort has cleared and is free of grain particles.

STEP 3 Runoff into the kettle and sparge with 180°F/82°C water.

STEP 4 Bring the wort to a boil, and add 60 minute hop addition.

STEP 5 After 45 min, add Whirlfloc for clarity and yeast nutrient for yeast health.

STEP 6 After 60 min, turn off the burner. Let the wort cool to about 204°F/96°C. Add the whirlpool hop additions.
Note: All whirlpool additions are calculated based on a 15 minute whirlpool starting at 204°F/96°C.

STEP 7 Gently create a whirlpool in the kettle.

STEP 8 Quickly cool the wort to 66°F/19°C, aerate it, and transfer in into a sanitized fermenter.

STEP 9 Pitch the appropriate amount of English Ale yeast and add either an airlock or blowoff tube to the fermenter.

STEP 10 Dry Hop 1: Add hops at the middle of active fermentation, with approximately 1.024 – 1.032 specific gravity left before final gravity.

STEP 11 After final gravity has been reached, add second Dry Hop for 2 days at 22°C/72°F.

STEP 12 After 2-3 days and the beer has passed forced diacetyl test, cool the fermenter to 32°F/0°C. Transfer to a keg and carbonate or bottle condition.

ALL-GRAIN RECIPE

YCH039

CRYO POP™ ORIGINAL BLEND BIOTRANSFORMATION JUICY PALE ALE

TASTING NOTES: TANGERINE • PINEAPPLE • PEACH • GRAPEFRUIT • CEDAR

SPECIFICATIONS

ORIGINAL GRAVITY	FINAL GRAVITY	IBU	ABV
1.059	1.014	27	5.9%

INGREDIENTS

GRAINS	AMOUNT
Pilsner Malt	90%
Malted Wheat	5%
Munich II Malt	5%
Acidulated Malt	As Needed

YEAST & ADJUNCTS	AMOUNT
London III	14.5 million cells/mL
Whirlfloc	Variable
Yeast Nutrient	Variable

HOPS	TYPE	AA%	ADDITION	AMOUNT
Cryo Pop™ Original Blend	Cryo Hops® Pellets	18.5%	Whirlpool	2.9 g/L
Cryo Pop™ Original Blend	Cryo Hops® Pellets		Dry Hop 1	3.9 g/L
Idaho 7® Brand	T-90 Pellets		Dry Hop 1	3.9 g/L
Citra® Brand	Cryo Hops® Pellets		Dry Hop 2	1.9 g/L

INSTRUCTIONS

STEP 1 Perform an infusion mash to achieve a mash temp of 154°F/68°C for 60 min.

STEP 2 Vorlauf until the wort has cleared and is free of grain particles.

STEP 3 Runoff into the kettle and sparge with 180°F/82°C water.

STEP 4 Bring the wort to a boil.

STEP 5 After 45 min, add Whirlfloc for clarity and yeast nutrient for yeast health.

STEP 6 After 60 min, turn off the burner. Let the wort cool to about 204°F/96°C. Add the whirlpool hop additions.
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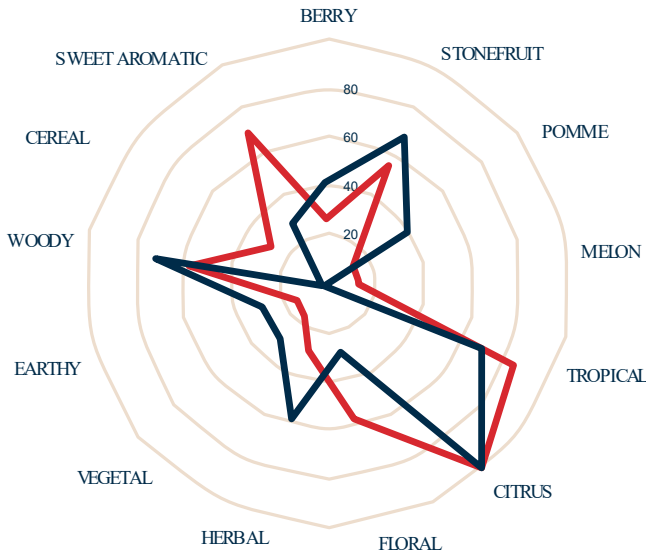
CRYO POP™ ORIGINAL BLEND



BEER SENSORY ANALYSIS

Active Fermentation

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

Post Fermentation

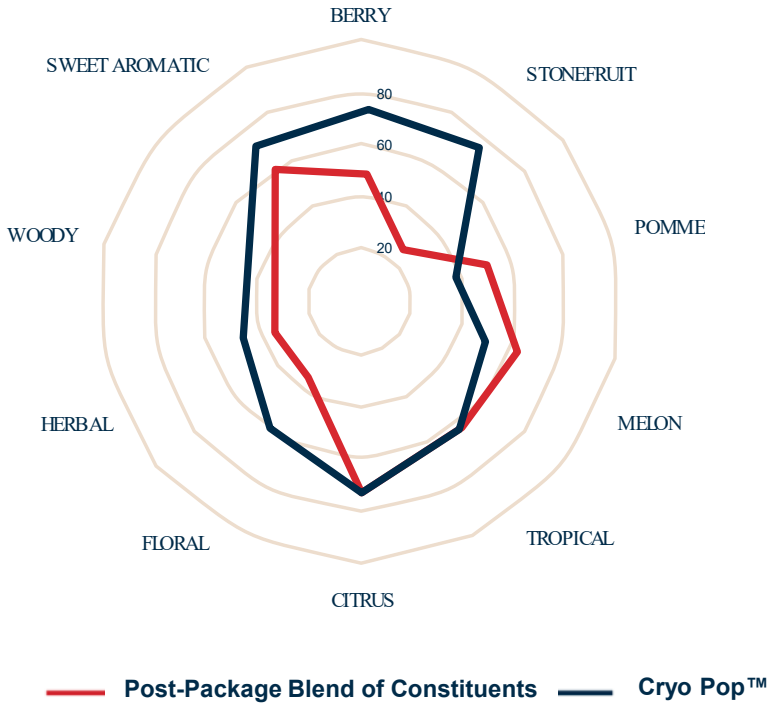
Peach, Grapefruit (50% each)
Mango, Pineapple, Pine, Hay (38% each)

Pages 22-24

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



HOP & BEER
SENSORY LEXICON

YAKIMA CHIEF HOPS®

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 • Skunky

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
Warming • Boozy

ASTRINGENCY
Drying • Grippy

BODY
Thickness • Fullness

CARBONATION
Bubble Size • Density

Pages 20-21

LEARN MORE AT CRYOPOPBLEND.COM