

BIOTRANSFORMATION & IPA SOLUTIONS



India Pale Ale (IPA) is a beer style defined by higher hopping rates. In the late 18th century, British brewers would preserve beer for export by using higher levels of alcohol and hops, thus introducing a recipe that became popular in British colonized India. The modern IPA family includes a diverse range of beer styles that are all defined by their very prominent hoppy character.

The choice of yeast strain is an important consideration in brewing any IPA style. Each yeast strain produces unique flavor compounds that directly impact the aroma of the final beer, from relatively neutral to more fruity esters. The level of attenuation will impact the body and perception of bitterness, and the genetics and metabolism of the yeast will impact the clarity of the finished beer.

Brewing labs are discovering how different yeast strains can influence flavor and aroma by interacting with specific hop-derived flavor compounds, a process collectively known as biotransformation. Yeasts produce enzymes that interact with hops to release or modify aromatic terpenes (citrus, floral) and thiols (tropical) to enhance the overall hop sensory profile. The combination of primary yeast metabolism (attenuation, production of esters, flocculation) and secondary interactions with hop compounds (biotransformation) will determine the flavor and aroma of the finished beer.

Lallemand Brewing's yeast strains, combined with our brewing expertise, empower brewers to achieve the desired hop-forward flavors for any IPA style.





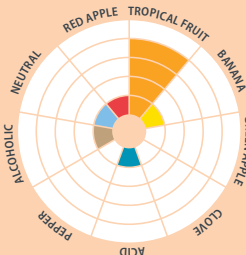
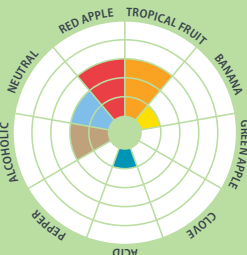
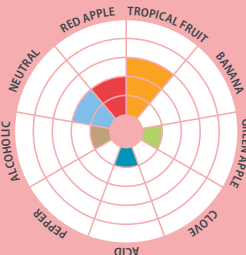
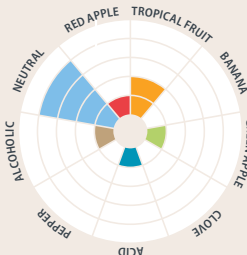




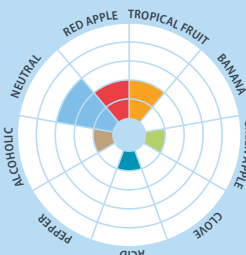
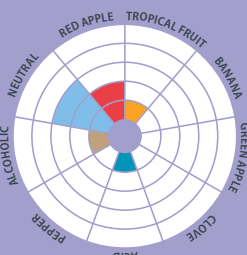
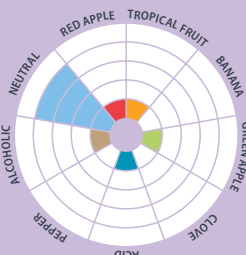
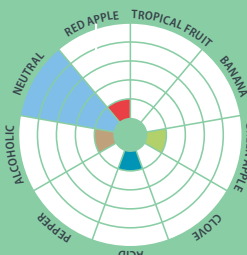
Throughout this document, we provide detailed information about LalBrew Premium® yeast strains, including the biotransformation potential of terpene and thiol compounds. We also discuss general strategies for optimizing the brewing process to maximize specific hop aromas. Armed with this data, the brewer is well equipped to choose the best yeast for each IPA style.

Lallemand Brewing is at the forefront of hop flavor and aroma research, and we are ready to help you with any questions about brewing hoppy beer styles.

LALBREW STRAINS BY BEER STYLE	BRY-97	LONA™	NEW ENGLAND	NOTTINGHAM	NOVALAGER	POMONA	VERDANT IPA	WINDSOR	VOSS
BLACK IPA	✓			✓			✓		✓
BRUT IPA	✓			✓					✓
COLD IPA					✓				
DOUBLE IPA	✓		✓	✓		✓	✓	✓	✓
ENGLISH IPA				✓			✓	✓	
NEW ENGLAND IPA			✓		✓	✓	✓	✓	✓
NON-ALCOHOL IPA		✓							
SESSION IPA	✓		✓	✓	✓	✓	✓	✓	✓
SOUR IPA	✓		✓	✓		✓	✓	✓	✓
WEST COAST IPA	✓			✓		✓	✓		✓

BEST PRACTICES

BIOTRANSFORMATION & IPA SOLUTIONS

				
ATTENUATION RANGE	75 - 84%	75 - 82%	78 - 83%	76 - 82%
FLOCCULATION	Medium	Medium	Medium	Very high
ABV TOLERANCE	10%	12%	9%	12%
BIOTRANSFORMATION POTENTIAL	Terpene: High Thiol: Medium	Terpene: Medium Thiol: High	Terpene: High Thiol: Low	Terpene: Medium Thiol: Low
FLAVOR & AROMA	Peach, citrus, and tropical fruits 	Apricot with notes of tropical fruit and citrus 	Fruity, tropical, stone fruits 	Relative neutral with slight orange and citrus notes 
				
ATTENUATION RANGE	65 - 72%	78 - 84%	78 - 84%	78 - 84%
FLOCCULATION	Low	Medium	High	High
ABV TOLERANCE	12%	13%	13%	14%
BIOTRANSFORMATION POTENTIAL	Terpene: Medium Thiol: Low	Terpene: Medium Thiol: Low	Terpene: High Thiol: Medium	Terpene: Medium Thiol: High
FLAVOR & AROMA	Fruity, estery 	Clean, low to medium esters 	Neutral with slight ester 	Slightly fruity, neutral 

Biotransformation Overview

Biotransformation is a term used to describe the transformation of compounds present in unfermented wort into altered, or altogether new, compounds by brewer's yeast. Non-aromatic compounds derived from hops are transformed by yeast enzymes, beta-glucosidase and beta-lyase, to release aromatic flavor compounds in the beer.

β -glucosidase activity results in the release of an aromatic terpene (and a glucose molecule) from a non-aromatic terpenyl glycoside. Additionally, specific terpenes can be modified by yeast metabolism

to produce different compounds with unique aromas (i.e. geraniol conversion to β -citronellol) (Figure 1). Terpenes can have diverse flavor impacts (citrus, floral) and higher levels of terpenes are associated with greater overall hop aroma intensity (OHA).

β -lyase activity results in the release of volatile sulfur compounds called thiols from non-aromatic precursors (Figure 2). Thiols are usually associated with tropical aroma and are active at very low flavor thresholds.

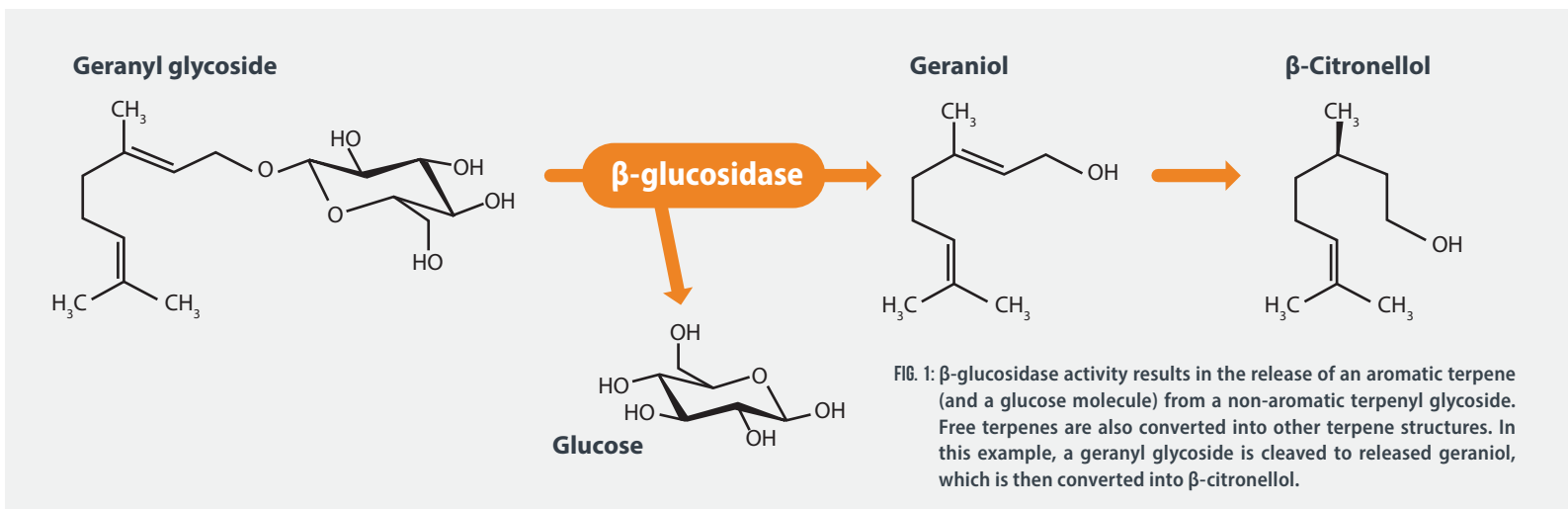


FIG. 1: β -glucosidase activity results in the release of an aromatic terpene (and a glucose molecule) from a non-aromatic terpenyl glycoside. Free terpenes are also converted into other terpene structures. In this example, a geranyl glycoside is cleaved to released geraniol, which is then converted into β -citronellol.

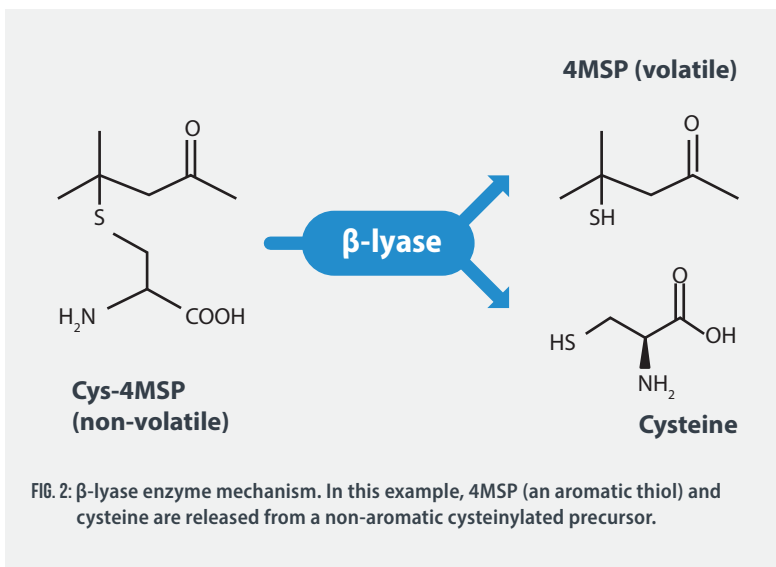


FIG. 2: β -lyase enzyme mechanism. In this example, 4MSP (an aromatic thiol) and cysteine are released from a non-aromatic cysteinylated precursor.

The flavor and aroma impact of hop biotransformation is a very active area of research, and Lallemand Brewing is at the forefront of biotransformation innovation. Through internal R&D and through collaborations with world renowned research institutions, we perform ongoing characterization of the biotransformation potential of our current yeast strains, and new strains in development. We are also exploring how enzymes such as ABV Aromazyme™ and inactivated specific yeast products such as ABV ISY Enhance™ can help brewers craft better IPAs and hop forward beers. For the most up to date information about biotransformation and brewing hop forward styles, please visit our website.

CLICK ON THE QR CODE TO LEARN MORE
www.lallemandbrewing.com/biotransformation



Optimizing Biotransformation

It is important to select ingredients to maximize the amount of aromatic precursors. Brewers should consider the type of malt, hop variety, point of hop addition, and yeast strain. Hops rich in bound precursors should be added in the whirlpool or early dry hop to allow the yeast enzymes (or exogenous enzymes) to release the aromatic compound. Hops that are rich in free terpenes or thiols should be added as a late dry hop to reduce aroma loss during fermentation. Different yeast strains have enzymes that are more specific to certain substrates and will tend to favor the formation of specific terpene or thiol compounds.

The following charts are a guide to help brewers optimize biotransformation during the brewing process in order to achieve specific hop aroma profile.

TERPENE TYPE

Whirlpool /Early Dry Hop

High in **bound** terpene

Fermentation

Maximize terpene **release**

Late Dry Hopping

High in **free** terpene



Geraniol

Rose, citrus, fruity

Hops: Motueka, Amarillo™, Chinook, Mosaic®, Comet, Hallertau Blanc, Vic Secret, Polaris, Summit, Cascade

Yeast: LalBrew BRY-97™, LalBrew New England™, LalBrew Voss™

Enzyme: Aromazyme

Motueka, Bravo, US Cascade, Mosaic®, Sorachi Ace, Citra®



Linalool

Lavender, sweet, fruity, spicy

Hops: Amarillo™, Glacier, Mt. Hood

Yeast: LalBrew BRY-97™, LalBrew New England™, LalBrew Voss™

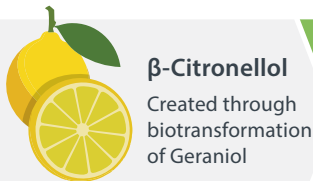
Enzyme: Aromazyme

Motueka, Southern Cross, Hallertauer Tradition, Amarillo™, Sorachi Ace, Coriander Seed

High in **free Geraniol**

Maximize terpene **conversion**

High in **free** terpene



β-Citronellol

Created through biotransformation of Geraniol

Lemon/lime, floral

Hops: Motueka, Bravo, US Cascade, Mosaic®, Sorachi Ace, Citra®

Yeast: LalBrew Pomona™

Motueka

THIOL TYPE

Whirlpool /Early Dry Hop

High in **bound** thiol

Fermentation

Maximize thiol **release**

Late Dry Hopping

High in **free** thiol



3SH

3-sulfanylohexanol

Malt: Pale pilsner / Lager
Hops: Motueka, Saaz, Cascade, Citra®, Hallertau Blanc

Yeast: LalBrew Nottingham™

Apollo, Galaxy®, Simcoe®, Citra®, Mosaic®



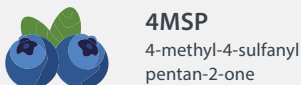
3S4MP

3-sulfanyl-4-methylpentan-1-ol

Hops: Hallertau Blanc

Yeast: LalBrew Nottingham™, LalBrew Verdant™, LalBrew Voss™

Nelson Sauvin, Ekuanot, Hallertau Blanc, Mosaic®



4MSP

4-methyl-4-sulfanyl pentan-2-one

Hops: Nelson Sauvin, Aramis, Strisselspalt, Mandarina Bavaria, Simcoe®

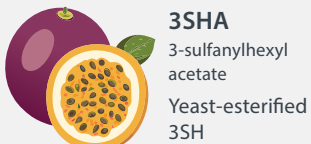
Yeast: LalBrew Nottingham™, LalBrew Voss™

Nelson Sauvin, Apollo, Citra®, Galaxy®, Mosaic®, Simcoe®

High in **free 3SH**

Maximize thiol **conversion**

High in **free** thiol



3SHA

3-sulfanylohexyl acetate
Yeast-esterified 3SH

Hops: Apollo, Galaxy®, Simcoe®, Citra®, Mosaic®

Yeast: LalBrew Nottingham™

None