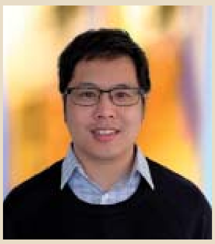
New Yeasts, New Beers: Non-GMO Technologies for New Beer Flavours (Part 2)

CONTROLLING YEAST | In the first part of this three-part article (BRAUWELT International No. 5, 2018, pp. 354-356), we outlined the enormous impact yeast has on the flavour and aroma profile of beer. In this second part, we discuss the variables and methods by which brewers can exert direct control over yeast during the brewing process. In the concluding article, we will examine the time-honoured, non-GMO classical development techniques by which new and exciting yeasts are being developed to help create whole new flavour and aroma profiles in beer.

OF ALL THE INGREDIENTS that contribute to a beer's makeup, *Saccharomyces* yeast is quite simply the only one over which brewers have total control. While the selection and application of the right hops and malt is certainly important, in reality it is the farmer and maltster who ultimately control the growing conditions and final product quality of these ingredients. This means that brewers must put some faith into factors outside the brewery's purview.



Authors: Jason Hung, Associate Scientific Research Writer, Jessica Swanson, Lead Development Scientist, Scott Bohanna-Martin, Development Associate Brewer, Matthew Dahabieh, Ph.D., Chief Science Officer, Renaissance BioScience Corp., Vancouver, Canada

Harnessing Yeast's Full Potential

That being said, many brewers may not fully appreciate how yeast grows, or how changes to brewing and fermentation conditions can affect the final sensory profile of beer. Perhaps the first thing to realize is that *Saccharomyces* yeast don't make beer – or any of the 183 chemical compounds that produce flavour and aroma in beer – for the benefit of the brewer or the consumer; *Saccharomyces* yeast make these compounds to thrive and survive in its environment. While not all of the mechanisms and pathways are fully understood, *Saccharomyces* yeast produce these compounds generally for four reasons: 1) energy metabolism; 2) detoxification; 3) competition for resources; and 4) cellular communication.

Managing Yeast Energy Metabolism

The most important of these is energy metabolism, often referred to as yeast growth. How well *Saccharomyces* yeast grow during the early stages of fermentation has a profound impact on the sensory profile of beer, and almost all environmental and biological factors that brewers can modulate will affect yeast growth in one way or another. Brewers must strike a delicate balance between having enough yeast biomass to reduce the lag period after pitching and not having too much yeast biomass; the latter would reduce ethanol production, cause downstream issues with filtration, and produce "yeasty" off-flavours due to autolysis. This would occur while also hindering the development of positive flavours and aromas.

Temperature is probably the easiest and most well-established factor brewers use to change the sensory profile of beer. Since fermentation itself is physically exothermic, when left unchecked the initial rapid growth phase of *Saccharomyces* yeast can raise the fermentation temperature by 4-5 °C. Higher fermentation temperatures also produce a positive feedback loop by increasing yeast growth and fostering the production of esters, but can also produce unwanted levels of fusel alcohols, diacetyl and acetaldehyde. However, higher temperatures are important near the end of beer fermentation to help it "finish strong" and aid in the metabolization of diacetyl and acetaldehyde into flavourless compounds. Today, brewers have access to precise temperature control via fermentation tanks fitted with glycol jackets and temperature regulators, but it should be noted that very cold fermentations (such as temperatures used to produce lagers) can have the opposite effect by producing only neutral beers, or by increasing the concentration of acetaldehyde, sulfur compounds and vicinal diketones (VDKs) due to sluggish yeast growth.

Wort Gravity and FAN

The next two factors to consider are wort gravity and free available nitrogen (FAN).

Compound Presence (%)	Yeast 1	Yeast 2	Yeast 3	Yeast 4	Yeast 5	Yeast 6	Yeast 7	Yeast 8	Chemical Name	Sensory Description
100	●	●	●	●	●	●	●	●	Octanoic Acid	Cheese, Fat, Grass, Oil
100	●	●	●	●	●	●	●	●	Propyl Alcohol	Alcohol, Candy, Pungent
100	●	●	●	●	●	●	●	●	Capric Acid	Dust, Fat, Grass
100	●	●	●	●	●	●	●	●	Linalool	Coriander, Floral, Lavender, Lemon, Rose
100	●	●	●	●	●	●	●	●	Isobutyl Alcohol	Apple, Bitter, Cocoa, Wine
100	●	●	●	●	●	●	●	●	Ethyl Propionate	Apple, Pineapple, Rum, Strawberry
100	●	●	●	●	●	●	●	●	Ethyl Butyrate	Apple, Butter, Cheese, Pineapple, Strawberry
100	●	●	●	●	●	●	●	●	Ethyl Heptanoate	Brandy, Fruit, Wine
100	●	●	●	●	●	●	●	●	Ethyl Octanoate	Apricot, Brandy, Fat, Floral, Pineapple
100	●	●	●	●	●	●	●	●	Propyl Acetate	Celery, Floral, Pear, Red Fruit
100	●	●	●	●	●	●	●	●	Isobutyl Acetate	Apple, Banana, Floral, Herb
100	●	●	●	●	●	●	●	●	Ethyl Acetate	Aromatic, Brandy, Grape
100	●	●	●	●	●	●	●	●	Hexyl Acetate	Apple, Banana, Grass, Herb, Pear
100	●	●	●	●	●	●	●	●	Propyl Hexanoate	Berry, Fruit, Petrol, Pineapple, Roasted Garlic
100	●	●	●	●	●	●	●	●	Isoamyl Hexanoate	Anise, Fruit, Spice
88		●	●	●	●	●	●	●	Methyl Salicylate	Almond, Caramel, Peppermint, Sharp
88		●	●	●	●	●	●	●	Ethyl Valerate	Apple, Dry Fish, Herb, Nut, Yeast
88	●	●		●	●	●	●	●	Isoamyl Acetate	Apple, Banana, Glue, Pear
75	●		●		●	●	●	●	3–(Methylthio)–1–propanol	Earth, Garlic, Potato, Soy
63			●	●		●	●	●	Methyl Sulfide	Cabbage, Organic, Sulfur, Wet Earth
63		●	●	●		●	●		Heptyl Acetate	Floral, Fresh
63	●	●	●	●	●				2–Methylbutan–1–ol	Fish Oil, Green, Malt, Onion, Wine
63		●		●	●	●		●	Caproic Acid	Cheese, Oil, Pungent, Sour
63		●	●	●	●	●			Ethyl Caproate	Apple Peel, Brandy, Fruit Gum, Overripe Fruit, Pineapple
50	●	●		●	●				Acetic Acid	Acid, Fruit, Pungent, Sour, Vinegar
50	●	●		●			●		Butyric Acid	Butter, Cheese, Sour
38	●	●					●		1–Octanol	Bitter Almond, Burnt Matches, Fat, Floral
38						●	●	●	Isobutyric Acid	Burnt, Butter, Cheese, Sweat
38			●				●	●	Acetal	Creamy, Fruit, Pleasant, Tropical Fruit
38						●	●	●	Ethyl Isovalerate	Apple, Fruit, Pineapple, Sour
38	●		●				●		Valeric Acid	Cheese, Pungent
38						●	●	●	1–Hexanol	Banana, Flower, Grass, Herb
25		●			●				Ethanethiol	Earth, Onion, Rubber, Sulfur
25	●				●				Phenethyl Acetate	Flower, Honey, Rose
25	●					●			Isoamyl Butyrate	Fruit
13								●	Butyl Alcohol	Fruit
13					●				Phenylacetaldehyde	Berry, Geranium, Honey, Nut, Pungent
13					●				Benzophenone	Floral
13								●	Farnesol	Oil
13								●	Furfural	Almond, Baked Potatoes, Bread, Burnt, Spice
13				●					Butyl Butyrate	Floral
13		●							2–Octanone	Fat, Fragrant, Mold
13			●						Undecanoic Acid	Oil
13							●		Ethyl 10–undecenoate	Green

Fig. 1 Yeast Sensory Chart

High-gravity brewing has become popular both to boost the production capacity of a brewery (without additional equipment) and to create strong beers. However, high-gravity brewing poses challenges to flavour-matching due to yeast off-flavours caused by osmotic stress and changes in the sequence of sugar uptake (carbon catabolite repression). High-gravity brewing has been shown to produce acetate esters at a higher rate than fusel alcohols, thereby shifting the ratio of fusels to esters. The utilization of greater proportions of maltose high adjuncts typically used in high-gravity fermentations has also been shown to exhibit reduced levels of esters and higher alcohols. Finally, high-gravity wort can produce off-flavour chemicals such as ethyl acetate, isoamyl acetate and ethyl hexanoate all exceeded their sensory threshold levels with both lager and ale strains. FAN levels can be controlled somewhat through proper adjunct selection. Generally, corn, rice and sugar contain lower FAN levels, while American barley and six-row barley varieties have higher levels (even compared to their European counterparts).

Aeration – or, more specifically, oxygen concentration – should also be quite familiar to brewers. The production of ethanol canonically occurs only in anaerobic (oxygen-depleted) environments, yet most *Saccharomyces* yeast have evolved the ability to produce ethanol even in the presence of oxygen (which is why open fermenters still produce beer). Increasing oxygen will stimulate yeast growth, and thus all of the aroma and flavour compounds linked to heightened growth rates (e.g., fusel alcohols, diacetyl and acetaldehyde) will also be elevated. Ester production is reduced in highly oxygenated worts because the cell utilizes its acetyl-CoA pool for cell membrane production (through sterol synthesis instead of ester formation). Decreasing oxygen, on the other hand, will likely produce more diacetyl and acetaldehyde in the finished beer due to incomplete fermentation and affecting re-pitching efficacy.

Another critical gas component in beer production is carbon dioxide concentration, often called CO_2 pressure. While many brewers don't think of CO_2 as a factor in the sensory profile of beer, it is a direct by-product of central carbon metabolism and alcoholic fermentation, and thus is the gas predominantly responsible for creating an anaerobic environment. Furthermore, CO_2 pressure inhibits fermentation speeds, reduces the production of esters, and fusel alcohols through hydrostatic pressure; some brewers leverage this through the use of spunding valves to mimic the pressure conditions of larger fermenters. Perhaps most importantly, CO_2 actually affects the sensory perception of flavour and aromas; although slightly bitter itself, CO_2 is the primary route by which more prominent aroma and flavour compounds become volatile in beer.

Re-pitching Issues and Challenges

Re-pitching yeast is unique to brewing and is known to create changes in any *Saccharomyces* yeast strain's flavour and aroma, especially if handled improperly. Brewers have found better success in consistency by removing and re-pitching the *Saccharomyces* yeast as quickly as possible or, when that isn't possible, storing it in cold, oxygen-limited environments. Regardless of steps taken to maintain consistency, genetic drift will occur between re-pitched generations of yeast, and this is exacerbated by the acid washing and oxidative stress caused by free radicals. It is believed that these stressors either alter the *Saccharomyces* yeast's DNA or select for specific subsets of *Saccharomyces* yeast with the predisposition to survive these harsh conditions. In reality, re-pitching can be thought of as slowly changing *Saccharomyces* yeast strains to the point (in extreme cases) where the strain in the first pitch can basically be thought as a completely separate *Saccharomyces* yeast strain from the tenth pitch. Of note, small genetic differences in yeast, such as those caused by re-pitching, can lead to large flavour and aroma differences in the final beer.

In one test, for example, eight *Saccharomyces* yeast strains were developed in-house using the same parental strains; these eight strains can be thought of as "siblings" of each other. Trials were done using a single batch of wort under identical brewing and fermentation parameters. The resulting eight beer samples were then analyzed via gas chromatography–mass spectrometry (GC–MS), and chemicals found within the yeast-derived flavour database were identified. Finally, the yeast-derived flavour compounds of each strain were compared with their "sibling" strains.

The test results showed that the amount of diversity in sensory profile from essentially "sibling" yeast strains is truly staggering: out of 44 unique yeast-derived flavour compounds, 15 were found in common between all strains, but 20 were found half of the time or less, with only 9 yeast-derived flavour compounds being found in only a single strain. Finally, the production of several off-flavours, such as butyric acid, valeric acid and acetic acid, can also be completely avoided by selecting the right *Saccharomyces* yeast. Obviously, if the diversity of flavour and aroma compounds is this great between closely related *Saccharomyces* strains, then the potential for non-related strains is exponentially greater.

Conclusion

Thus by capitalizing on the principles of proper selection and control of *Saccharomyces* yeast, brewers can enjoy incredible control over the final flavour and aroma profile of their beer. Selecting the right *Saccharomyces* yeast, producing a good wort, and optimizing brewing conditions – temperature, oxygen and CO_2 among other factors – can separate a good beer from a great one. But what if the *Saccharomyces* yeast strain you truly want for your beer continues to elude you? Worry no more: the technology is now available to make a designer yeast just for you.

Part 3 of this series will be published in BRAUWELT International No. 1, 2019. ■

Sources

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