Make Your Beer Stand Out: The Key to Yeast Fermentation

Karen Fortmann, Ph.D.
White Labs, Inc.
San Diego, CA
A Little Bit About White Labs
Why I’m Standing Here in Front of You

White Labs Motto – “To be the best yeast company in the world”
A Brief Outline

• Introduction:
  • Yeast in the brewing process
  • What is yeast?
  • *Saccharomyces cerevisiae*
  • Species of brewer’s yeast
  • Unique properties of brewer’s yeast & how this effects brewers

• Flavor and a little bit of metabolism:
  • Alcohol production in beer
  • Basic flavor components in beer
  • Basic Metabolism
  • Important fermentation flavors and some critical control points
An Introduction to Brewing and Yeast

“The basics”
For Those Who Don’t Know...

**Malting**
- Barley
  - Steeping & Germination
  - Drying & Kilning
  - Malt

**Mashing**
- Malt
  - Water
  - Milling
  - Adjuncts
  - Heating
  - Wort

**Fermentation**
- Wort
  - Fermentation
  - Conditioning & Maturation
  - Beer

**Post-Fermentation**
- Beer
  - Clarification & Filtration
  - Packaging & Pasteurization
  - Beer
Brewing Raw Materials
• Morphological term meaning “single celled organism”
• In everyday language, yeast is synonymous with *Saccharomyces cerevisiae*
  • There are over 1500 species of yeast
• Ubiquitous in nature
  • Yeast are found in every biome and continent
  • Especially on fruits and vegetables
Saccharomyces cerevisiae

- One of the oldest domesticated organisms
  - Used for brewing beer in Sumeria and Babylonia around 6000 BC
- Saccharomyces = sugar fungus; cerevisiae = Roman Goddess of crops – Ceres
- Used as a eukaryotic model organism
  - Unicellular, doesn’t need a lot of room to grow, eukaryotic → can be applicable to humans
  - 1st genome to ever be sequenced in 1996
Types of Brewer’s Yeast

**Saccharomyces cerevisiae**
- Ale yeast
  “Top fermenting”

**Saccharomyces pastorianus**
- Lager yeast
  “Bottom fermenting”

Other Hybrids?  
- Saccharomyces carlsbergensis  
- Saccharomyces uvarum  
- Saccharomyces bayanus  
- Saccharomyces eubayanus  
- S. cerevisiae + S. eubayanus

All yeast used in brewing worldwide are non-GMO
## Unique Properties of Brewer’s Yeast

<table>
<thead>
<tr>
<th>Lab Strains</th>
<th>Brewing Strains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haploid or diploid</td>
<td>Polyploid and aneuploidity</td>
</tr>
<tr>
<td>Sporulating</td>
<td>Sporulate poorly</td>
</tr>
<tr>
<td>Spores viable</td>
<td>Spores mostly non-viable</td>
</tr>
<tr>
<td>Able to mate (a &amp; α mating types)</td>
<td>Mating Rare</td>
</tr>
</tbody>
</table>
Alcohol Production in Beer

Yeast → Sugar → CO₂ → Ethanol
Flavor & (a little!) Metabolism

Why yeasts are so important to you as a brewer!
Sugar → Glycolysis → Pyruvic Acid

- 2 ATP

- Fermentation:
  - Lactic Acid
  - Ethanol

- Oxygen?

- Respiration:
  - Up to 36 ATP
  - CO₂ & H₂O
Yeast Produce over 500 Flavor Active Compounds!

The byproducts: (besides ethanol and CO2)

- Esters
- Alcohols (fusel)
- Vicinal diketones (diacetyl, 2,3-pentandione)
- Aldehydes (acetaldehyde)
- Organic acids
- Sulfur compounds
- Fatty acids
Yeast Flavor & Aroma

Remain at Levels Produced After Primary Fermentation
- Esters
- Higher alcohols
- Sulfur dioxide
- Phenols

Decline During Beer Maturation
- Acetaldehyde
- Diacetyl
Yeast Flavor Development

Fig 2.3 Yeast: The Practical Guide to Beer Fermentation, White and Zainasheff 2010
Esters

**Flavors** - fruity, banana, apples, perfume, solvent, nail polish remover

- **Formation**
  - Reaction of alcohol group and acid group in the yeast cell
  - Alcohol part comes from ethanol and fusel alcohols
  - Acid part comes from various acids that are inside the yeast (acetyl-CoA compounds)
  - Reaction is catalysed by an enzyme (alcohol acetyltransferase)
Esters

Control

- Ester synthesis not that simple.
- No direct relationship between yeast growth and ester synthesis.
- Strain dependent

Formation depends on:

- The amount of the acid (acetyl-CoA compounds)
- The amount and activity of the enzyme (Alcohol acetyltransferase)
- The amount of the higher alcohol
- Low temperature = low esters
- More Oxygen = low esters
- Highly yeast strain dependent
- More problematic in very strong beers
- May be symptom of Acetobacter
Higher (Fusel) Alcohols

**Flavor** - alcoholic, spicy, vinous, warm

**Formation**
- Intermediates in amino acid metabolism
- Produced during uptake of amino acids
- Produced from glucose when yeast needs to make amino acids
- Directly related to yeast growth
Higher (Fusel) Alcohols

Control

• Any conditions that stimulate yeast growth will stimulate fusel alcohol production
  • Aeration
  • Lipid (fat) content of the wort
  • Trub
  • Agitation
  • Temperature
Sulfur Compounds

Flavor - sulfury, rotten eggs, burnt rubber, striking a match

Formation
- Intermediates in amino acid metabolism
- When yeast needs to make sulfur containing amino acids

Control
- Wort oxygen content (more is better)
- Fermentation temperature
- Yeast “health”
Phenolic Compounds

Some yeasts are able to convert phenol carbon acids into phenols in the beer:

- **Phenolic Off Flavor (POF)** - POF positive yeasts are generally unwanted in brewing (wild yeast characteristics)
  - **Exception** - Bavarian Hefeweizen style where the phonal 4-Vinyl Guiacol is a desired compound due to its clove character as well as some Belgian beers

**Flavor** - Clove, solvent, plastic, bandaid, smoke (Wild/Belgian!)

**Formation:**
- During primary fermentation
- POF positive yeasts decarboxylate cinnamic acid derivates in wort to produce vinylphenols
Diacetyl

**Flavor** - Buttered popcorn, butterscotch, sweet yogurt, slick mouthfeel

**Formation:**
- Precursor (α-AL) produced during primary fermentation
- α-AL is converted to diacetyl outside cell
- Diacetyl is again taken up and metabolized by yeast during maturation
- Reaction related to amino acid synthesis
- pH and temperature dependent
Importance of Conditioning Time

The diagram illustrates the metabolic pathway involving glucose, pyruvate, acetaldehyde, ethanol, acetoin, diacetyl, and 2,3-butanediol. Conditioning time is crucial for the conversion of ethanol to acetoin and diacetyl, which are important in the production of flavors in beverages.
Acetaldehyde

Flavor - Grassy, green apples

Formation:
• During primary fermentation, then reduced during maturation
• Intermediate of alcoholic fermentation pathway
• Metabolized to ethanol during maturation

Control:
• Healthy yeast
• Adequate conditioning time
• Temperature
Importance of Conditioning Time

Glucose

Pyruvate

Pyruvate decarboxylase

Acetaldehyde

Alcohol dehydrogenase

Acetaldehyde dehydrogenase

Ethanol

Acetate

Acetyl CoA
Conclusions & Take Away

• Yeast metabolism is a complex biological process

• Don’t worry about understanding the complex details!

• The more you know the better you can control your fermentations
  • Controlled fermentations = Better Beer!
A Guided Tasting

Thank you!
Questions?
kfortmann@whitelabs.com