Beauty and the Yeast - part II

Factors Affecting Fermentation and how to control them

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Agenda

• Yeast metabolism basics - Flavor creation
• Yeast handling
  - Pitching
  - Fermentation
  - Collection, storage and reuse
The Brewers’ Legacy

Throughout history brewer's yeast has been continuously selected to meet the brewers’ demands.

The selection techniques have over the years become more refined and controlled resulting in an enormous variety of characterized strains with unique characteristics available to the brewer today.

A unique difference from other fermented foods including wine.
Brewers domesticated *Sacch. cer.*!
Unique Properties of Brewers Yeast

- Asexual reproduction by budding
- Little to no sporulation - therefore mating is rare
- Polyploid
- Phenol Flavor Negative (group 1)
- Stress tolerant
- Flocculate
- Hundreds of different, stable strains currently used industrially
Why are Strains so Important:

**Flavor**

- Alcohol
- Higher (fusel) alcohols
- Esters
- Diacetyl
- Sulfur
- Acetaldehyde
- Phenolic compounds

*Different Yeast strains make different amounts
Different Beers often require different yeast strains*
Creativity!

Yeast does not care about making beer, it only cares about creating energy to survive and reproduce.

The yeast’s aroma contribution to the beer can be visualized as a spill or overflow of the building blocks needed for cell replication.

59% of the *aroma* descriptors in beer

79% of the *flavor* descriptors in beer are yeast derived or modified by Yeast.
Fermentation Recap

First few hours
- The yeast uses all the dissolved oxygen; there is no detectable uptake of glucose.

8-16 hours
- The first sign of active fermentation as CO2 bubbles are formed.
- A thin head of foam can be observed.

24 hours
- Budding yeast cells observed.
- The temperature, if uncontrolled, rises due to heat generated by the fermentation.

24-48 hours
- The rate of yeast growth and carbohydrate assimilation reaches a maximum.

Post 48 hours
- The pH falls to a minimum of 3.8 - 4.4 before rising slightly towards the end of fermentation.
- The fall in pH is caused by the release of organic acids and buffering compounds (basic amino acids and phosphates) being consumed by the yeast.

Figure 1. Fermentation profiles, showing relative changes taking place.
Yeast’s flavor and aroma contribution to beer
3 Variables (You Can Control!) in Fermentation

- Pitch Rate
- Fermentation Temperature
- Dissolved Oxygen

Fermentation Rate
Final Gravity
Flavor
Yeast Handling – What Do We Mean?

• Best practices for working with yeast
  – Maintaining a pure culture
• Avoiding contamination by bacteria, wild yeast, or cross-contamination of brewing strains
  – Maintaining a healthy culture
  – Minimizing stress to yeast
Pitching Yeast

Adding a specific amount of yeast to freshly oxygenated wort, at the correct fermentation temperature

- Yeast can be new, first generation, or reused from previous fermentation
- Yeast can be reused ??? times.
  - Can be 5-10, can be 600 → mutations will occur but brewers choice
- Pitch more yeast for high gravity beers
# Yeast Pitching Rate

<table>
<thead>
<tr>
<th>Low Pitching Rates</th>
<th>High Cell Growth</th>
<th>Increased Flavor Compounds</th>
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<tbody>
<tr>
<td>High Pitching Rates</td>
<td>Low Cell Growth</td>
<td>Decreased Flavor Compounds</td>
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Rule of thumb: “1 million cells per ml of *wort* per degree Plato”
Yeast Health

• 1 million cells/ml/°Plato is based off re-pitching rates
  – This is assuming this yeast has undergone the stressful conditions of fermentation
  – Actual pitching rates vary between .75 – 1.5 million cells/ml/°P

• Yeast grown in a lab is much healthier than the yeast at the bottom of your fermenter
  – Grown in the presence of O2
  – Low alcohol production
  – Pure culture
  – High viability (95%+)
Yeast Pitching: A Common Brewery Practice

1 liter of yeast slurry per 1 HL of beer is a good rule of thumb.

In a 10HL batch:
10 liters of yeast at 1 billion/ml, would
Result in 10 million/ml in 1000 L
Yeast Pitching Rate

- **Underpitching**
  - Pros
    - Possibly enhanced yeast flavor
    - Need less yeast
  - Cons
    - Stuck fermentation
    - Stressed yeast, less viable to use again

- **Overpitching**
  - Pros
    - No stuck fermentation
    - Decrease in some aromas/ flavors
  - Cons
    - Fermentation completes too quickly
    - Can leave some off flavors
    - Ageing yeast culture for re-pitching
Yeast Pitch Rate

Effect on growth rate and flavor byproducts:

Percent of Cell Mass Increase

<table>
<thead>
<tr>
<th>Initial Pitch Count</th>
<th>Count of initial pitch</th>
<th>Count at peak growth</th>
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</thead>
<tbody>
<tr>
<td>10mil cells</td>
<td>244%</td>
<td></td>
</tr>
<tr>
<td>20mil cells</td>
<td>85%</td>
<td></td>
</tr>
<tr>
<td>30mil cells</td>
<td>54%</td>
<td></td>
</tr>
<tr>
<td>40mil cells</td>
<td>52%</td>
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</tbody>
</table>
Pitch Rate and Flavor

Yeast Count

Metabolites (flavor-active compounds)

Fermentation Speed (short lag, but can get sluggish)

Yeast Count

= Yeast Metabolites

= Fermentation Speed

= Yeast
Fermentation Temperature

• Temperature affects both yeast metabolism and the speed of fermentation
• Most S. cerevisiae strains are optimal between 65-70°F (18-21°C), but there is a wide range
• Higher or lower temperatures can lead to varying fermentation effects

Temperature – one of the most important control factors
Fermentation Temperature

Temperature = Metabolites (flavor-active compounds)

Fermentation Speed = Temperature

Temperature = Yeast Metabolites

inhibitory

Fermentation Speed =
Dissolved Oxygen

- Oxygen is necessary for production of lipids for cell wall manufacture.
- Allows the yeast to be hardy and withstand environmental stresses (gravity, pH changes, temperature, alcohol).
- Optimal is 8-10ppm in wash, prior to fermentation.
Dissolved Oxygen

- Oxygen
- Unsaturated Fatty Acids
- Sterols

Lipids
Dissolved Oxygen

Without it, yeast are depleted

Resulting in:

Slow fermentation

Incomplete fermentation

Poor growth
Dissolved Oxygen = Yeast Metabolites = Fermentation Speed

Metabolites (flavor-active compounds) = Fermentation Speed = Yeast Metabolites (ca to stuck fermentations)
Yeast Collection & Harvesting

*When is the best time to harvest?*

- End of fermentation
- When early flocculating yeasts begin to drop to the bottom of the cone – discard
- Within 3-5 days of start of fermentation
Yeast Collection & Harvesting

How should yeast be collected?

Top Cropping

• Benefits
  – Yeast rises at a time of high vitality and viability
  – Free from trub – better shelf life
  – Faster turnaround time for yeast collection

• Disadvantages
  – Beer & yeast are exposed to environment
Yeast Collection & Harvesting

*How should yeast be collected?*

**Bottom Cropping**

- **Benefits**
  - Equipment design lends well to bottom cropping
  - Some strains can’t be cropped from top
- **Disadvantages**
  - Breakdown of yeast happens faster – stress from hydrostatics, alcohol, temperature
  - High percentage of trub
  - Turnaround time to collect yeast is longer
Yeast Collection & Harvesting

*How should yeast be collected?*

• Bottom Cropping – Best practices
  – Timing – end of fermentation, depending on strain
    • Remove as soon as possible without risking integrity of beer
  – Discard the first runnings
  – Use only the middle pack
  – Measure crop (number of buckets? weight)
Yeast Collection & Harvesting

How should yeast be collected?

Cone to cone?

• Need to visually verify yeast
  – Color
  – Trub
  – Concentration
  – Contamination analysis

Aber instrument
Collection Options
Storage

• Cone storage can be stressful
  – Hydrostatic pressure
  – Inhospitable environment – alcohol
  – Temperature in the cone

• Storage Medium:
  – On beer, wort, or water?
    • Beer – no transfer; great short term if under 6% alcohol
    • Wort – short term; carbohydrates present can be harmful
    • Water – best long term solution because it’s neutral
Storage

Considerations for yeast storage:

Objective:

Keep metabolic activity to an absolute minimum in order to preserve viability and vitality

1. Chilling the yeast
   - If warmer than $4^0\text{C}$
     - Alcohol toxicity
     - Limited nutrients
     - Depletion of glycogen
     - Loss of viability / vitality
2. Glycogen and lipids

• Glycogen is the major reserve carbohydrate stored within the yeast cell.

• “Store” of to sustain the cell during periods of starvation

• In the presence of oxygen, glycogen is rapidly mobilized to fuel lipid (sterol and unsaturated fatty acids) synthesis.
Yeast Glycogen and Lipid during a 16 °P Lager Fermentation

C.R. Murray, T. Barich and D. Taylor
MBAA Technical Quarterly, 21 (4) 1984
The Effect of Yeast Glycogen Concentration at Pitching on a 16°P Lager Fermentation

C.R. Murray, T. Barich and D. Taylor
MBAA Technical Quarterly, 21 (4) 1984
Yeast Maintenance

Re-pitching yeast – what to expect

• How many generations? – conditions & strain
  – Ales: 8-10
  – Lagers: 3-5
  – Wheat & Belgian: 3 or less

• First generation vs. later generations – why the differences?
Summary

- Harvest yeast as soon as the bulk of the yeast has separated from the beer
- Chill rapidly to ~ 4°C and maintain that temp
- De-carbonate
- Exclude air
- Store for as short a period as possible
- Pitch accurately
- Evaluate the culture before using/reusing
- Keep it clean
Thank you

Questions?
Extra material
Fermentation Control - Strain Selection

- Set Parameters for the beer
  - ABV, IBU, SRM
- Decide on a flavor concept
  - Malty, hoppy, other?
- Determine at least 1 or 2 key requirements
  - Temperature, sugar, and alcohol tolerance, attenuation ranges, volatile flavor and fusel alcohol production, etc.
Monitor the Actual Values

- Gravity
- pH
- Cells in suspension
- Cell Pack
- Alcohol
- Color
- Clarity
- IBU
- Aroma

The list goes on……

Google sheets (free), excel, fancy software
Fermentation Monitoring

*Do experiments!*

Ferment the same wort with different yeast strains
6Dry or Liquid?!
Water is life
Dehydration is damaging

- ester production muted
- background contamination
- low viability
- not suitable for reuse