Brewing yeast – theory and practice

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Topics

• What is brewing yeast?

• Yeast properties, fermentation and beer flavour

• Sources of yeast

• Measuring yeast concentration
The nature of yeast

• Yeast are unicellular fungi

• Characteristics of fungi:
  • Complex cells with internal organelles
  • Similar to plants but non-photosynthetic
  • Cannot utilise sun as source of energy so rely on chemicals for growth and energy
Classification of yeast

Kingdom

Moulds

Yeast

Fungi

Mushrooms / toadstools

> 500 yeast genera

Genus
Saccharomyces

(Means “Sugar fungus”)

Species

S. cerevisiae
(ale yeast)

S. pastorianus
(lager yeast)

Many thousands!

Strains
Biology of ale and lager yeasts

- Two types indistinguishable by eye
- Domesticated by man and not found in wild
- Ale yeasts – *Saccharomyces cerevisiae*
  - Much older (millions of years) than lager strains in evolutionary terms
  - Lot of diversity in different strains
- Lager strains – *Saccharomyces pastorianus* (previously *S. carlsbergensis*)
  - Comparatively young (probably < 500 years)
  - Hybrid strains of *S. cerevisiae* and wild yeast (*S. bayanus*)
  - Not a lot of diversity
Characteristics of ale and lager yeasts

**Ale**
- Often form top crops
- Ferment at higher temperature (18 - 22°C)
  - Quicker fermentations (few days)
- Can grow up to 37°C
- Fine well in beer
- Cannot use sugar melibiose

**Lager**
- Usually form bottom crops
- Ferment well at low temperatures (5 – 10°C)
  - Slower fermentations (1 – 3 weeks)
- Cannot grow above 34°C
- Do not fine well in beer
- Can use sugar melibiose
Growth of yeast cells via budding
Yeast cells

- Each cell is *ca* 5 – 10 microns in diameter (1 micron = 1 millionth of a metre)
- Cells multiply by budding

Yeast and ageing - cells can only bud a certain number of times before death occurs.
Yeast dispersion and flocculation

• Flocculation – ability of yeast cells to bind together
• Flocculence - inherent genetic property of yeast strain
  • Some are flocculent and some are not!
  • Most brewing strains are at least moderately flocculent
• Flocculation – expression of flocculence
  • The process by which it occurs
  • Determined by expression of flocculation genes
  • Clumping characteristic turned on or off
How does flocculation work?

- **Involves interaction between adjacent yeast surfaces**
  - Calcium mediated process – activate the flocculins

- **Receptors are present in ALL yeast cells**
  - Flocculent and non-flocculent

- Zymolectin protein (Flocculin)
- Mannan receptors
Effect of wort sugars

- Sugars present in the wort can also bind to the receptor sites
  - Prevents flocculins attaching and causes cells to ‘deflocculate’

- Zymolectin protein (Flocculin)
- Mannan receptors
- Wort sugar
Flocculation works to advantage of brewer

- Sugars (including glucose, maltose and sucrose) block receptor sites and cause yeast cells to de-flocculate
  - Ensures cells are dispersed at start of fermentation

- Disappearance of sugars allows flocculation (but requires the presence of calcium)
  - Crop formation occurs when all sugar has been fermented by yeast
Cropping characteristics

• Ale strains have more hydrophobic surface
  • Traps CO₂ bubbles
  • Causes clumps to rise

• Lager strains have less hydrophobic surface
  • Form clumps and drop out to bottom

• Differences are not absolute
Brewing yeast strains

- Many thousands of individual strains, both ale and lager
- Result of slight differences in genome (DNA)
- Differences produce differences in fermentation behaviour and beer properties
- Most brewing companies use own proprietary strains
What contributes to beer flavour?

- Grist materials
- Hops
  - Bittering
  - Aroma types
- Liquor
- Yeast?
Contribution of yeast

- Conversion of sugar to alcohol and CO$_2$
- During fermentation
  - Yeast removes many undesirable wort components
  - Yeast produces many thousands of flavour-active beer components
Yeast beer flavour compounds

- Ethanol (alcohol)
- CO$_2$
- Higher alcohols
- Esters
- Organic acids
- Glycerol
- Warming
- Mouth tingle
- Wine, warming
- Fruity, floral
- Sharp
- Fullness
Does the yeast strain matter?

- Identical samples of filtered green beer (made with same yeast strain)
- Bottled after seeding with different yeast strains
- Bottle conditioned under identical conditions
<table>
<thead>
<tr>
<th>Yeast strain</th>
<th>Tasting notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK Ale 1</td>
<td>Fruity, warming</td>
</tr>
<tr>
<td>UK Ale 2</td>
<td>Estery, floral</td>
</tr>
<tr>
<td>UK Ale 3</td>
<td>Sulphidic, dry</td>
</tr>
<tr>
<td>US West coast ale</td>
<td>Vanilla, sweet</td>
</tr>
<tr>
<td>Nottingham ale</td>
<td>Thin, bland</td>
</tr>
<tr>
<td>Munich strain</td>
<td>Malty, mellow</td>
</tr>
<tr>
<td>Lager 1</td>
<td>Herbal</td>
</tr>
<tr>
<td>Lager 2</td>
<td>Bland, faint ester</td>
</tr>
<tr>
<td>Champagne strain</td>
<td>Catty, antiseptic</td>
</tr>
<tr>
<td>Cider strain</td>
<td>Sweet, toffee</td>
</tr>
<tr>
<td>Belgian Saison</td>
<td>Fruity, estery</td>
</tr>
</tbody>
</table>
Choice of yeast strain

• Need to consider all attributes of strain
  • Ability to ferment
  • Impact on flavour
  • Cropping behaviour
  • Flocculation characteristics
  • Temperature dependence
  • Alcohol tolerance
  • Genetic stability

• Impact on beer
  • Appropriate strain for chosen beer style
    • Could be single pure strain or mixture of yeast and possibly bacteria

• Impact on process
  • Choice of fermentation system
  • Strain used for primary fermentation not always best for cask or bottle conditioned beers
Sources of yeast

• Traditional process uses “wet yeast”
  • Sourced either in bulk or as a pure lab culture
    • Purchase from brewery
    • Commercial brewing yeast suppliers
    • Yeast culture collections

• Dried yeast
  • Many brewing strains available in dried form
    • Suitable strains for most beer styles
    • Supplied in vacuum packs in various sizes to suit brewing scale
Wet yeast handling

Propagation

Periodic introduction of new culture

Yeast pitch

Discard

Crop

Store

5 - 20 cycles
Wet yeast handling

• Complex and testing operation
  • Big emphasis on good hygiene
  • Cropped yeast must be stored appropriately
    • 2 – 4°C, 5 days max
  • Brewery propagation plant
    • Requires lab facilities
  • Wort must be oxygenated / aerated

• “Free” yeast supply
• Independent of dried yeast suppliers
• Wide choice of strain
• Can contract out propagation to third party supplier
Dried yeast operation

1. Vacuum packs
2. Re-hydrate
3. Pitch
4. Crop and discard

- Crop and retain
- Re-pitch
- Becomes conventional wet operation
Dried yeast handling

• Much simpler operation
  • Unopened vacuum packs stable for *ca* 1 year if held in fridge
  • Pitching rate control via addition of known weight
  • No need to crop and store
  • No need for wort oxygenation / aeration

• Constant on-cost of yeast
• Quality dependent on supplier
• More limited choice of strain
• Exposure to air in dried form results in rapid death
  • Store opened packs wrapped to exclude air and in deep freeze
• Must carry out rehydration step properly
Ideal rehydration procedure

• Use 10x boiled tap water or treated brewing liquor at ca 30°C for ale strains [DO NOT USE DEIONISED WATER OR WORT]

• Sprinkle yeast on surface [DO NOT STIR]

• Leave for 15 min

• Stir gently and leave for 5 min

• Dilute with water to lower temp to pitching temp.

• Pitch

• NEVER PITCH DRIED YEAST DIRECTLY INTO WORT
Yeast and oxygen

- Yeast requires oxygen for proper growth in fermentation
- Consequence of serial cropping and repitching
- Oxygen is used for synthesis of membrane lipids in initial aerobic phase
- Subsequent growth in anaerobic phase dilutes lipids between mother and daughter cells
- Resultant lack of proper membrane function eventually limits growth
- Dried yeast is pre-loaded with lipids and does not require wort oxygenation if only used once
Measuring yeast concentration

• Required for:
  • Control of pitching rate
  • Monitoring end fermentation counts
  • Control of cask / bottle conditioning counts

• Measured directly via microscopic yeast counts or indirectly as wet cell mass (wt/vol or wt/wt or vol/vol)

• Additional determination of proportion of living cells (viability) allows correction for pitching rates and monitor of yeast quality
Assessing yeast concentrations

• Typical pitching rate:
  • 1lb pressed yeast per UK barrel @1040
    • Equivalent to 2.8g/litre
  • In terms of cell numbers:
    • Roughly equivalent to 10 million cells per ml
  • Can use either cell mass or cell count
Analysis of slurry for solids

- Usual to use centrifuge
  - Spin known weight slurry
  - Pour off barm ale
  - Weigh packed yeast

- Quick method
  - Take known weight of slurry
  - Place in graduated container
  - Allow yeast to settle and assess solids content
Analysis based on yeast weight

Example:
Total weight slurry = 50g
Weight yeast = 20g
Yeast concentration = \( \frac{20}{50} \times 100 \)
= 40% w/w
Analysis of slurries by cell count

- Use microscope to count individual yeast cells in sample of slurry

- Use special slide - haemocytometer
  - Contains chambers of known volume
  - Contains grids to make counting easier

- Can use with dyes which differentiate between live and dead cells
  - Allows calculation of viability
    - Dead cells $\times$ 100 = $\%$ viability
    - Total cells
Assessment of viability

- Industry standard method uses dye, methylene blue
- Live cells are colourless
- Dead cells stain blue
Use of haemocytometer

• Prepare diluted suspension of slurry
• Mix slurry with equal volume of methylene blue solution
• Count total number of cells
• Count blue stained cells
• Calculate no. cells in original slurry
• Calculate viability
Summary

• Yeast is the brewery’s most precious asset!

• Choose the correct strain
  • Beer style
  • Brewery plant
  • Brewing process

• Guard its welfare carefully