Yeast and Fermentation

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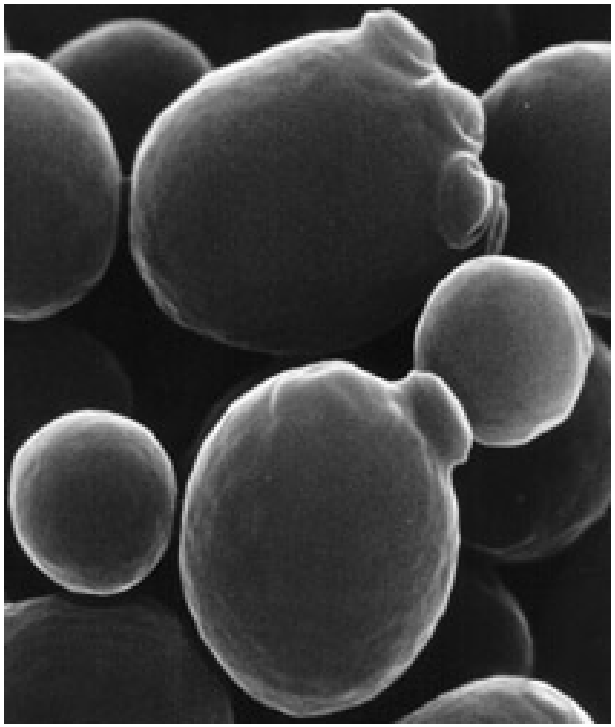
What is Yeast?

- A single-celled organism
  - Very heavily studied
- Turns sugars into alcohol
- Used for years without knowing
  - Role identified ~1875



http://www.genomenewsnetwork.org/articles/07_02/yeast_unknown.shtml

Ale Yeast

- *Saccharomyces cerevisiae*
- Top-fermenting yeast
- Optimal temperature ranges 60-72ºF
- Tend to create more flavor compounds than lager yeasts
- Several different classes
  - Clean ale yeasts – American Ales
  - Fruity ale yeasts – British Ales
  - Phenolic ale yeasts – Belgian Ales, Weizens

Lager Yeast

- *Saccharomyces pastorianus* (*carlsbergensis*)
- Isolated at Carlsberg brewery in 1883
- Colder optimum fermentation temperatures – 40-55ºF
  - At higher temperatures more off flavors produced
- Able to process more complex sugars than ale yeasts
- Different profile than ale yeasts
  - Fewer esters, fusel alcohols
  - More prone to sulfur
  - More prone to diacetyl

Attenuation

- The ability of the yeast to ferment the sugars in the wort
- Measured as apparent attenuation
  - (OG-FG)/OG
  - 15ºP wort – 3ºP beer → 80% attenuation
- Actual attenuation is lower than apparent (~65%)
  - Density of alcohol is lower than water

- Largely governed by choice of yeast strain
  - Which types of complex sugars the yeast can process

Alcohol Tolerance

- Alcohol is a product of fermentation
- Tends to be toxic to yeast at high levels
  - Also inhibits other microorganisms
- Alcohol tolerance of yeast is strain dependent
  - For high alcohol beers need to choose the right strain
  - Lager yeasts tend to be lower than ale yeasts

Flocculation

- How quickly the yeast falls out of suspension
- Highly flocculent yeasts may leave behind more fermentation byproducts
- Highly flocculent yeasts give clear beer more quickly
- Highly flocculent – drop out quickly
  - English ale yeasts
- Low flocculation – will stay in beer for longer time
  - Most lager yeasts

Fermentation Steps

- Sugars are transported into cell from surrounding wort
- Some simple sugars are transported directly
  - Glucose, fructose
- Some complex sugars are broken down outside cell
  - Sucrose, Melibiose
- Some complex sugars are transported into cell by enzymes then broken down
  - Maltose, Maltotriose

Fermentation Steps 2

- Glucose is broken down into alcohol and CO_2
- Glucose → 2Pyruvic Acid → 2Acetaldehyde → 2EtOH + $2CO_2$
- Fermentation of glucose provides energy for the cell
- An alternate pathway to breaking down sugars exists
  - Requires the presence of oxygen
  - Creates more energy, does not lead to alcohol
- Flavor compounds produced are all minor byproducts of this process

Yeast Life Cycle – Lag Phase

- Usually lasts 1-12 hours
- Yeast adapt to the new environment
  - Assess oxygen levels
  - Assess nitrogen, nutrient levels
- Produce enzymes that will be needed for fermentation
- Using up glycogen reserves

- Lag can be longer with unhealthy starting yeast

Yeast Life Cycle – Growth Phase

- Yeast divide to reach fermentation density
  - Usually 1-3 divisions
- Oxygen used up to create sterols
  - Necessary for healthy cell walls
- Begin to bring simple sugars into cell
- Off-flavors are dependent on this stage
  - Ester production

Yeast Life Cycle – Low Kräusen

- Beginning of anaerobic fermentation
  - Starting with simple sugars, maltose
- Visual foam wreath begins to cover center of liquid
- Several off flavors can be produced
  - Fusel alcohols
  - Diacetyl

Yeast Life Cycle – High Kräusen

- Most active portion of fermentation stage
- Ale yeast will consume almost all sugars they can
- Lager yeasts still working on more complex sugars
  - e.g. Maltotriose

Yeast Life Cycle – Late Kräusen

- Fermentation is pretty much complete
- Yeast will reabsorb and metabolize some fermentation byproducts
  - Diacetyl
  - Acetaldehyde
- Yeast will also flocculate out at this point
- Important not to drop temperature when yeast are still working on clean up

Yeast Pitching Rates

- One important step in producing good beer is to pitch a sufficient quantity of healthy yeast
- “1 million cells per mL wort per degree Plato”
  - Higher for lagers, lower for ales
  - For a 1.048 ale that means 180 billion cells
    - Wyeast or White labs tube are ~ 100 billion cells
- Pitching insufficient yeast is a big problem
  - Off flavors, low attenuation
- Overpitching is less of a concern but also not good

Yeast Growth and Flavor

- Many flavor compounds are produced during growth phase and early fermentation
- More yeast growth will favor off-flavors
- Compounds are produced and “leak” out of cell
  - May be reabsorbed later

- Flavor active compounds only require low levels

Fusel Alcohols

- Fusel alcohols are higher chain length alcohols
  - Propanol, butanol, isoamyl alcohol, etc.
- Give beer a “hot”, “solventy” taste
- Much lower flavor threshholds than ethanol (50-800 g/L)
- Produced from amino acids in malt
- Factors that cause higher fusels
  - Higher fermentation temperature
  - Higher wort OG
  - Wrong oxygenation or FAN
  - Low pitch rate

Esters

- Fruity compounds of an alcohol and an acid
  - Most noticed esters are from fusel alcohols
- Range from solvent, banana, other fruits
- Largely dependent on yeast growth
- Factors that cause high esters
  - Yeast strain choice
  - High fermentation temperature
  - High wort OG
  - Low oxygenation, pitching rate

Diacetyl

- Member of class of compounds called vicinal diketones
  - Diacetyl – butter
  - 2,3-pentanedione – honeylike
- Produced from acetaldehyde in early stages of ferment
- Can be reabsorbed by yeast and level reduced
  - Reduction faster at warmer temperatures
- Factors that cause high diacetyl
  - Yeast strain choice
  - Removing beer from yeast too quickly
  - Late oxygen introduction
  - Bacterial contamination

Acetaldehyde

- A precursor to ethanol on fermentation pathway
- “Green-apple” like character

- Factors that cause high acetaldehyde
  - Removing beer from yeast too quickly
  - Oxidation after fermentation
  - Inadequate oxygen before fermentation

Kräusening

- Adding actively fermenting beer to finished beer
- Traditional German technique
- Serves 2 main purposes
  - Natural source of carbonation
  - Cleans up off flavors from fermentation
    - Reduce diacetyl
    - May result in slightly more acetaldehyde

Brettanomyces

- Another type of yeast, beyond ale and lager
- Actually Brettanomyces is the genus
  - *B. bruxellensis*, *B. lambicus*, *B. anomalus*
- Flavor characteristics
  - Horse blanket, barnyard, leather, mousey
- Most commonly found in Belgian style beers
- Produces sour characteristics as well

Fermenting Bacteria

- *Lactobacillus delbruckii*
  - Common beer spoiler
  - Desired in Berliner Weisse
- Pediococcus
  - Also largely produce lactic acid
- Acetobacter
  - Produce acetic acid
  - More active in the presence of oxygen
- These can also produce other off-flavors
  - Diacetyl

Brewing Process Questions

- *Describe the five stages of yeast development and give five considerations in selecting the appropriate yeast strain for a given beer style.*

- Five stages of yeast development
  - Lag phase, growth phase, low kräusen, high kräusen, late kräusen
- Five considerations
  - Attenuation, alcohol tolerance, diacetyl production, flocculation, ester profile, phenolic production, ale vs. lager (temperature)