Malting Overview

- Raw barley kernels are soaked in water, then allowed to germinate.
- Partial germination breaks down walls inside the kernel. Enzymes that degrade starch are released, and 30-40% of the protein is degraded to soluble compounds (important for FAN).
- The kernels are dried and heat cured.
- Optional kilning for color and flavor.
Temperature and Malting

- Where is temperature important and why?
  - Soaking
  - Germination
  - Production of Crystal Malt
  - Kilning
  - Roasting
Soaking

- When barley arrives it is dry
- Grain is soaked to hydrate the kernels and give them the signal to sprout and grow
- Too cold or too hot and the barley doesn’t germinate
- Optimum temperature: 60.8-64.4°F
- Grows 25% during this process
Barley is then drained and held at a constant temperature (60°F) for close to 5 days until it starts to sprout.
Drying and Curing

- The barley is slowly dried in a kiln at temperatures gradually rising to 185 F for lager malts and 221 F for pale ale malts. This kiln drying takes about 30 hours.
- The moisture content lowers from 40-45% to 2-4%

<table>
<thead>
<tr>
<th>Czech Pilnener</th>
<th>185°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic 2 row</td>
<td>189.5°</td>
</tr>
<tr>
<td>Pale-ale/Vienna</td>
<td>194°</td>
</tr>
<tr>
<td>Munich</td>
<td>221°</td>
</tr>
</tbody>
</table>
Kilning

- The kilning temperature affects how dark the malt will be, what flavors it will impart, and its active enzyme levels
- S-Methyl-Methionine (SMM)
- Maillard Reaction
Precursor to dimethyl sulfide (DMS)
Desired in some beers
Converted to DMS either during kilning or during the boil
DMS produced during kilning is quickly degraded and is not present in finished malt
For SMM in malt, temperature does not exceed 149°
Browning reaction involving an amino acid and a sugar + heat

Produces flavor compounds (melanoidins and heterocyclic compounds) that add “toasty”, “burnt”, “caramel”, “smoky” malty flavors and aromas

Occurs at ~212º F

2-acetyl pyrazine
Crystal Malt

- Produced by holding the wet warm barley post-germination at a set temperature
- Partially mashes and liquefies the starch
- Accomplished by holding the grain at 149-158º for 30 mins-2 hours and then continuing to dry/cure
- Dark crystal is obtained by elevating the temperature to 248-302º for 1-2 hours
- Carapils is dried at a lower temperature
Roasted Barley

- The very rapid color development that occurs is monitored by inspecting grain samples, which are taken every 2-3 min. The amount of heat applied in the final stages is continually reduced until, when the temperature reaches about 419°F, the burners are turned off. However, the grain is near combustion and the temperature continues to rise spontaneously for the last 5 min or so to about 425°F.
- When the operator judges the color is correct (just before the grain catches fire) the barley is cooled with sprays of water. The risk of fire is great and roasthouses are generally isolated and constructed with this risk in mind.
- All enzymes and sugars are consumed...
Mashing

- Starch is converted to sugars by enzymes
- Proteins are broken into peptides
- Glycoproteins are formed
- Percent fermentability is determined
Protein Rest

- Not usually required for well-modified modern malts
- Proteins and polypeptides broken down into amino acids by proteases and peptidases (enzymes)
- Raises the free amino nitrogen (FAN) level
- Occurs at 116-125º F
- FAN is required by yeast for cell growth
- Too much FAN can cause production of fusel alcohols
Starch

- Made of amylose and amylopectin
- Glucose units are bound together with two different bonds
- Gelatinizes at 141º

Native Starch Types

[Diagram showing the structures of amylose (linear) and amylopectin (branched)]

M. Hubbe
Starch breakdown by amylase

- Starch is broken down by two types of amylases, $\alpha$ and $\beta$.
- $\alpha$ amylase breaks 1-6 links.
- $\beta$ amylase breaks 1-4 links to produce maltose.
- $\beta$ amylase will not break link where a 1-6 bond is present.
High fermentability produces a drier beer.

Low fermentability produces a sweeter beer with higher terminal gravity.

$\beta$ amylase denatured at 158º.
Sugar Solubility

- Hot water holds more sugar than cold water
- Affects efficiency
Phenols during sparging

- Sparging extracts unwanted phenols from grain that add astringency (tannins). Imparts clove, medicinal, plastic, band-aid, electrical fire
- Not very soluble in water, but can become more so
- More related to pH than temperature, but sparge temperature is a factor
- Critical temperature for phenol extraction is 170º
- Optimum sparge temperature is 165-167º
The Boil - Temperature-related chemistry

- DMS formation
- More Maillard reactions
- Hot-side aeration
- Hop isomerization
- Hop oil evaporation
- Protein break
- Haze
DMS Formation

- DMS formation is related to temperature and time
- Forms from S-methyl methionine in malt
- SMM has a half-life of 40 minutes at 212°
- Most DMS evaporates during the boil
- DMS in wort is formed during cooling
- Faster cooling significantly reduces DMS levels in wort
- Fermentation at ambient temperatures reduces DMS level by 50%
More Maillard reactions!

- Maillard reactions during the boil make the wort darker
- Create delicious caramel, nutty flavors
- High-temperature boils can cause undesirable heterocyclics to form (cooked cabbage, sweet corn, vegetal, astringent)
Oxidation reaction causes cardboard taste
Melanoidin (Maillard Product) is oxidized in the presence of heat
Held in check during fermentation and maturation by yeast, then goes to town forming aldehydes
Other major player: trans-2-nonenal (T-2-N)
Reduce by more vorlauf/slower sparge for bright clear wort
2 types of acids $\alpha$ and $\beta$

- Chemical difference is the OH group attached to the ring
- $\alpha$ acids are not very soluble, but are more soluble when isomerized
- Isomerized $\alpha$ acids inhibit gram-negative bacteria reproduction
After harvest, hops begin to lose their alpha acid content. The rate of loss is halved for every 27 ° drop in temperature.

To minimize the amount of alpha acid loss, hops should be stored in a cold, dark place, and in packages that are free of oxygen.

Some hop varieties store better than others. For example, Cascade hops stored at 68 ° will typically lose 50% of its alpha acids after 6 months storage, while Galena usually will lose only 15% under the same storage conditions.

\[ A_t = A_0 \times e^{-k \times TF \times SF \times t} \]
α acids in hops change form to become more soluble, requires heat
Isomerized cohumulone more soluble than humulone, gives a harsher bitter
Noble hops (Hallertau, Saaz, Tettnang) have low cohumulone levels

\[
IBU = \left( 1.65 \times 0.000125 \left( \frac{G_{\text{gravity}}}{1} \right) \right) \times \left( \frac{1 - e^{-0.04 \times t_{\text{min}}}}{4.15} \right) \times \left( \frac{\alpha \% \times W_{\text{oz}} \times 7490}{V_{\text{gallons}}} \right)
\]
The lovely smell during the boil is your hop aroma escaping.

Adding hops near the end of the boil reduces the amount of α acid isomerization and gives the hop oils less time to evaporate.

Related to temperature due to evaporation.
Breaks

- Two breaks occur – hot and cold
- Hot break is caused by protein coagulation and denaturation, just after the boil starts
  - Lots of foam, causes boilovers
- Cold break happens during chilling
  - Proteins precipitate and drop to the bottom
  - Reduces chill haze
Haze

- Haze happens when proteins become less soluble and make beer hazy
- Chill Haze happens when beer gets close to 32º
  - More stable beer (less protein) has a lower chill haze temperature
- Permanent haze happens. Made worse by high temperatures
  - Rule of thumb: 1 week at 100º is equal to a month at 65º
Fermentation

- Overview
- Products
- Byproducts/Off Flavors
Fermentation overview

- Yeast turns sugar into energy by removing the hydrogen that is attached to the carbon molecules, producing water, CO₂, and energy (ATP)
In the absence of oxygen, the necessary precursors are not formed and the cycle breaks.

Fermentation is a less efficient way of breaking down sugar when no oxygen is present.

Produces CO$_2$, ethanol, and energy.
Fermentation Temperature

- Lagers *(Saccharomyces uvarum)*: 32 to 55°
- Ales *(Saccharomyces cerevisiae)*: 50 to 75°

- Rules of thumb, there are exceptions
  - Steam beer uses lager yeast at ale temperatures
Off flavors related to temperature

- Fusel
- Astringent (Already covered)
- Diacetyl
- DMS (Already covered)
- Ester
- Phenolic (Already covered)
- Sulphur

- Dependent on yeast strain
Fusel alcohols

- Hot, spicy, solventlike
- Produced by high fermentation temperatures
- Avoid by using the right yeast strain and control fermentation temperature

propanol (disagreeable alcohol)  isoamyl alcohol (bananas, solvent)
Diacetyl

- Butter or butterscotch
- Produced during normal fermentation, and converted to 2,3-butanediol (which has no flavor or smell)
- Incomplete reduction caused by weak yeast
- Warmer fermentation reduces the amount of diacetyl by increasing yeast metabolism
- Diacetyl rest used in lagering
Esters

- Banana, grapefruit, raspberry, pear, apple, strawberry
- Desired in certain styles
- Acetylaldehyde oxidizes to acetic acid and reacts with alcohols to produce esters
- Ester formation is directly related to high fermentation temperatures

\[
\begin{align*}
\text{Acetic acid} & \quad \text{isoamyl alcohol (bananas, solvent)} \\
& \quad \rightarrow \\
\text{isoamyl acetate (banana smell)} & \quad + \text{H}_2\text{O}
\end{align*}
\]
- Rotten eggs, burnt match
- Hydrogen sulfide is produced by yeast during fermentation, usually carried away with the CO₂
- High levels are almost always caused by bacterial infection, but can also be caused by overpitching or an inappropriate temperature for your strain
Beer is carbonated by exposure to pressurized CO\(_2\), either in a keg or in bottles.

- Carbonation level is measured in volumes.
- 1 volume = 1 L of CO\(_2\) per liter of beer at STP.
- Works out to 0.0444 mol CO\(_2\) per liter (1.95 g).

<table>
<thead>
<tr>
<th>Beer Style</th>
<th>Volumes of CO(_2) Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Ales</td>
<td>1.5 - 2.0</td>
</tr>
<tr>
<td>Poter &amp; Stout</td>
<td>1.7 - 2.3</td>
</tr>
<tr>
<td>American Ales and Lagers</td>
<td>2.2 - 2.7</td>
</tr>
<tr>
<td>European Lagers</td>
<td>2.2 - 2.7</td>
</tr>
<tr>
<td>German Wheat Beers</td>
<td>3.3 - 4.5</td>
</tr>
<tr>
<td>Belgian Ales</td>
<td>1.9 - 2.4</td>
</tr>
<tr>
<td>Lambic</td>
<td>2.4 - 2.8</td>
</tr>
<tr>
<td>Fruit Lambic</td>
<td>3.0 - 4.5</td>
</tr>
</tbody>
</table>
Related to temperature, pressure

Ideal gas law: \[ PV = nRT \]

Pressure and temperature are directly related

The gas in your CO₂ tank is no exception, shows less psi when cold

CO₂ in beer or in a gas under pressure is trying to escape

- Higher temperature means the CO₂ is trying harder to escape
- Lower the temperature, and the beer holds more carbonation
Recap: Temperature is important
For BJCP members: This talk was worth CEP points

Next month I’ll be talking about yeast propagation, culturing yeast from wild yeast, or from a sample
I’ll also be giving out pitchable amounts of Belgian yeast harvested from the Westvleteren strain, cultured on Petri dishes, and propagated from a single colony
- This yeast will be used for the September Style Competition, Belgian Strong Ales (single strain)
March Style Competition Program

- Beers were brewed using the same recipe and yeast strain. Temperature was left up to the individual.
- Go taste the beer that people brought and look at the sheets to see what differences you can taste and identify.
- Thanks to everyone who participated.