Identifying and Avoiding Oxidation

AHA Homebrew Con 2016 – Baltimore, MD
Brian Bergquist

- Started brewing in 2008
- Won first medal (2010)
- Opened The Brew Shop (2010)
- MCAB Gold in Porter (2012)
- Dominion Cup Plato Award (2012)
- Joined BJCP (2013)
- Became Master judge (2015)
- Current President of FBI (Fredericksburg Brewing Insiders)
- NHC Finals for last 5 years
- NHC Medal (???)

- Lots of early notes of oxidation
- Most beers judged (homebrew & commercial) show some signs of oxidation

Some oxidation

A little touch of papery oxidation

Oxidation faults

Overall Impression
Comment on overall drinking pleasure associated with entry, give suggestions for improvement

The oxidation faults here are pretty bad, resulting in some musty / choppy / cardboard / papery notes that are out of place.

Oxidized – Any one or combination of stale, winy/vinous, cardboard, papery, or sherry-like aromas and flavors.

Beer seems a bit aged as indicated by papery note in aroma and
What is Oxidation?

**Oxidation** is the loss of electrons or an increase in oxidation state by a molecule, atom, or ion. **Reduction** is the gain of electrons or a decrease in oxidation state by a molecule, atom, or ion.

- **Redox** is a contraction of the name for a chemical *reduction–oxidation reaction*
- As with all chemical reactions, accelerated with heat and motion

\[
\text{CH}_3\text{-CH}_2\text{OH} \xrightarrow{\text{oxidation}} \text{CH}_3\text{-C} = \text{O} \\
\text{Ethanol} \quad \text{Acetaldehyde}
\]
Oxygen & Oxidation

- **Oxidizers** – Have the ability to oxidize other substances (gains electron)
  - Oxygen is a strong oxidizer, but not the only one
  - Oxygen catalyzed with metals (copper, iron) will form highly reactive radicals which rapidly react with beer components
  - Hydrogen peroxide, bleach (chlorine) will also oxidize

- **Reducers** – Substances that have the ability to easily reduce (looses electron)
  - Sodium/Potassium Metabisulphite
  - Ascorbic Acid (Vitamin C)
  - Reductones – Naturally occur in beer

- Air contains 21% oxygen
- Reduction Potential – Ability to reduce oxidation
Trans-2-nonenenal (Papery)

- Tastes like cardboard/wet paper
- Aldehyde / Carbonyl
- Mainly caused by oxidation of lipids and oxidized free fatty acids
  - Linoleic & linolenic acids from malted barley
- Flavor threshold about 0.1 ppb.
- Sulphites interact with trans-2-nonenenal resulting in a loss of papery character
- Possibly created in malting/HSA
Oxidation Flavors in Beer

- Malt phenols – Reduction of flavor/aroma, malt astringency
- Hop polyphenols – Reduction of flavor/aroma, harsh/astringent
- Melanoidins – Natural anti-oxidants
  - Honey, toffee flavors (2,3-pentanedione) – cloying notes
  - Sherry/vinous with high alcohols (Benzaldehyde / Almond)
  - Needed for oxidation of alcohols
- Dark malts – Anti-oxidants, may develop soy sauce, metallic flavors
- Fatty acids (Excessive trub) - Soapy/goaty
- Hop acids – Valeric (Cheesy, sweaty sock) and butyric (vomit) acids
- Hop oils – Grassy, woody
- Darkening of color
- Ribes (Rye-Bees) – Blackcurrent leaves (Fruity) / catty flavor - overripe or spoiled fruit or vegetables
- Cidery/sherry – Acetaldehyde(old/rotten apples) and acedic acid (vinegar)
Oxidation Flavors Over Time

Fig. 1. Sensory changes during beer aging according to Dalgliesh (1977).
Malt Oxidation

- Kernel protects malt from oxidizing
- Once crushed, will oxidize much more quickly
- **Moisture** will degrade kernel and stale malt
- Musty, stale, loss of rich grain flavors
- Store in a cool, dry place. Use sealed buckets or pet food containers
Hot Side Aeration

Hot side aeration is a myth, right?
Hot-Side Oxidation (HSO)

- Malt lipids, fatty acids, phenols, and melanoidins oxidize even during malting
  - Happens even faster at mash/boil temperatures
    - 4-5ppm in mash water, 1-3ppm from dough in, 1-2ppm from env.
  - Boiling wort will remove oxygen, not oxidation
- Oxidized compounds can act as oxidizers after fermentation
  - Oxidation without molecular oxygen causes oxidation of beer alcohols and the creation of volatile aldehydes
  - Bonds between the aldehydes and natural sulfur compounds from yeast metabolism will break eventually, releasing aldehydes
  - Usually 3-4 weeks after fermentation is finished
- Any splashing of hot wort (> 80f) can cause HSO
- Total exclusion of HSO can cause haze instability
Hops Oxidation

- Pellet last longer than whole leaf
- Oils and alpha acids will degrade together
  - Beta acids get bitter when oxidized
  - Alpha:Beta ratio will show storage potential
- Keep cold and away from oxygen
  - Vacuum packed and stored in freezer
- Look/feel/smell all hops before using
- Reject brown, cheezy hops – Got a spare?
Wort Aeration

- Want to add oxygen, not oxidation!
- Wort should be below 80f, preferably already pitched
- Up to 8-14 ppm $O_2$ into chilled wort will help create sterols for the yeast to replicate
  - Too much $O_2$ is toxic to yeast
- For high gravity beers, you can oxygenate multiple times (until beginning of active fermentation)
- 60 seconds with pure $O_2$
- Cannot over-oxygenate with sterile air (8ppm max)
- Once fermentation begins, protect from all air/$O_2$

The following data, and derived graph has been taken from “Worts & Coolers” by Moll, from a lecture Krauss, EBC conference 1967

<table>
<thead>
<tr>
<th>Temperature °C</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O_2$ dissolved in water</td>
<td>14.5</td>
<td>12.7</td>
<td>11.2</td>
<td>10.0</td>
<td>9.9</td>
</tr>
<tr>
<td>$O_2$ dissolved in 12% wort</td>
<td>11.6</td>
<td>10.4</td>
<td>9.3</td>
<td>8.3</td>
<td>7.4</td>
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</table>
Cold-Side Aeration (CSA)

- All air/oxygen contact after fermentation will oxidize
  - Will oxidize slower at lower temperatures
- TDO – Total Dissolved Oxygen (dissolved in solution)
  - Can be measured with TDO meter
  - From transfers/packaging, splashing
- TPO – Total Packaged Oxygen (TDO+Headspace)
- 20-30 years ago, 1000 ppb TPO (1ppm) acceptable
- Pros shoot for < 100 ppb TPO (.1 ppm)

### Effect of Thermal Abuse and Headspace Air on Staling

<table>
<thead>
<tr>
<th>Headspace air (mL per 1/3 L)</th>
<th>Storage at 86 °F (30 °C)</th>
<th>Storage at 43 °F (6 °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>1.0</td>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>1.5</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>2.0</td>
<td>5</td>
<td>70</td>
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</table>

Data obtained from test brews that were carefully controlled with respect to HSA and other forms of CSA.
Avoiding CSA – The Basics

- If possible, purge all receiving vessels with CO₂
- Careful racking to avoid splashing
  - Starsan in top of auto-syphon to reduce bubbling
  - Rack with CO₂ pressure into purged vessel
- If long term aging
  - Avoid any headspace not purged
  - Avoid buckets or other permeable materials (Silicone stoppers)
- Do not add water (unless de-aerated) after fermentation
- Yeast is an oxygen scavenger, especially when active

<table>
<thead>
<tr>
<th>Tank</th>
<th>O₂ cc/l/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE Bucket</td>
<td>220</td>
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<tr>
<td>Homebrew barrel</td>
<td>23</td>
</tr>
<tr>
<td>Class Carboy, 30cm vinyl immersion tube</td>
<td>0.31</td>
</tr>
<tr>
<td>Class Carboy, silicone stopper</td>
<td>17</td>
</tr>
<tr>
<td>Class Carboy, wood stopper</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Cold Crashing

- As beer and airspace cool, they shrink
- Will pull in air to replace the vacuum
- If possible, crash under CO$_2$ pressure
- If not, capture CO$_2$ produced during fermentation?
Secondary

- Really a clearing stage
  - Is there a true secondary fermentation?
- Reduce headspace as much as possible
- Purge receiving vessel
- Purge all transfer lines
- Timing is everything – is it still producing CO$_2$?
- Is it really worth it?
Dry Hopping

- Dry hop near the end of fermentation in the primary vessel
  - Fermentation will scrub any oxygen introduced
  - May also drag out the hops
- Dry hop in the keg
  - Keep gas (1-2 psi) on while keg is open to provide positive pressure
- Dry hop using a hop rocket
  - Purge all lines with CO₂ before starting
  - Push beer from one keg to another through the dry hops
  - Too many passes will result in grassy notes
Bottle Conditioning

- No access to CO$_2$?
- Boil priming sugar solution to remove O$_2$
- Careful (quiet) racking into bottling bucket
- Fill bottles from bottom
- Additional fermentation and yeast will scrub excess O$_2$
- O$_2$ barrier caps – Keep air out
- O$_2$ absorbing caps – Oxygen scrubbing
  - Must be activated in (warm) water/liquid
Purging a vessel with CO₂

- There is no CO₂ blanket
- CO₂ will mix with time, currents
- Putting CO₂ into a container filled with air will dilute the air, not replace it
- Best Method: Fill container to be purged with de-aerated water/starsan, then push out liquid under CO₂ pressure.
- Still leaves residual O₂
  - Airspaces in lid/cap
  - O₂ in starsan comes out of solution
  - Krausen/Active fermentation
Kegging

- Purge kegs completely
  - Fill with starsan/pre-boiled water then push out with CO₂
  - Uses less CO₂ than purging with PRV
  - Store sanitized, pressurized kegs
- Fill kegs through ‘out’ side
  - Add liquid QD to your auto-syphon or racking cane
  - Release pressure from PRV while racking
# Purging the Keg – PRV Release

<table>
<thead>
<tr>
<th>Purge Cycles</th>
<th>10</th>
<th>12.5</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
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<td>210000.00</td>
<td>210000.00</td>
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<td>113492.65</td>
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<td>3</td>
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<td>4</td>
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<td>5</td>
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<td>6</td>
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<td>13</td>
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<td>14</td>
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<td>15</td>
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<tr>
<td>18</td>
<td>18.42</td>
<td>3.25</td>
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<td>0.04</td>
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<tr>
<td>19</td>
<td>10.96</td>
<td>1.76</td>
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<tr>
<td>20</td>
<td>6.53</td>
<td>0.95</td>
<td>0.16</td>
<td>0.01</td>
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</tr>
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Thanks to HomeBrewTalk member doug293cz for the chart.
Purging the Keg – PRV Release

Thanks to HomeBrewTalk member doug293cz for the graph
Racking under CO$_2$ pressure
Bottling from the keg

- As with all vessels - Purge
- Counter-pressure bottle filler
- Beergun
- Others?
  - Can they purge the bottle?
- Cap on foam!
- Add additional priming sugar?
Summary

- Use fresh ingredients
- Dark malts, melanoidins, and hops scavenge oxygen
- Minimize hot-side aeration
- Practice zero-oxygen contact on cold side
  - Completely purge all receiving vessels
  - Rack using CO₂ pressure to purged vessel
  - Cap on foam!
- Keep finished beer as cold as possible and drink fresh!
- How much oxidation is acceptable?
Thank you!
Brian Bergquist

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