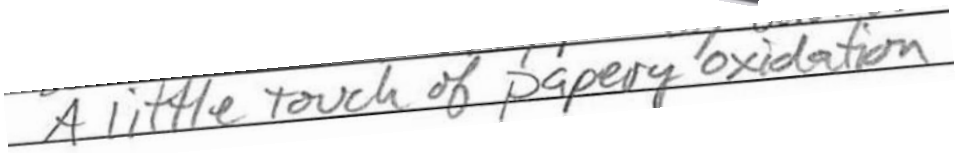
Identifying and Avoiding Oxidation

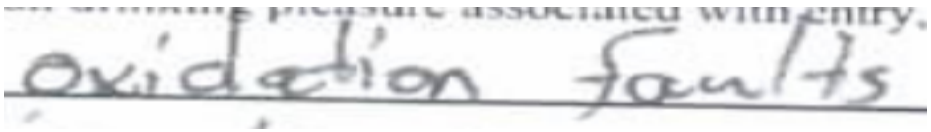
AHA Homebrew Con 2016 – Baltimore, MD

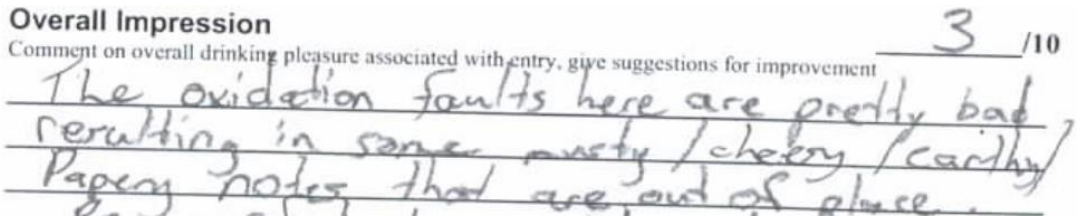
Brian Bergquist

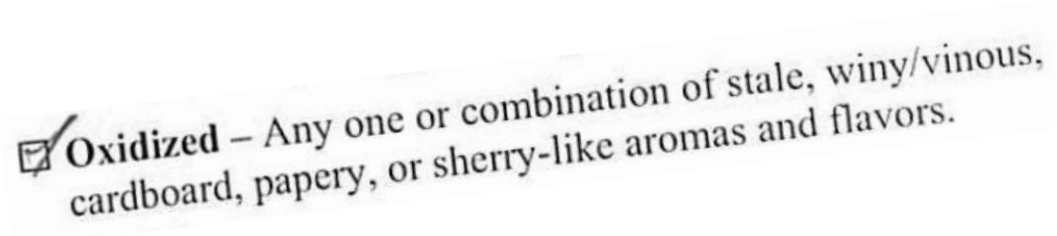
- Started brewing in 2008
- Won first medal (2010)
- Opened The Brew Shop (2010)
- MCAB Gold in Porter (2012)
- Dominion Cup Plato Award (2012)
- Joined BJCP (2013)
- Became Master judge (2015)
- Current President of FBI (Fredericksburg Brewing Insiders)
- NHC Finals for last 5 years
- NHC Medal (???)

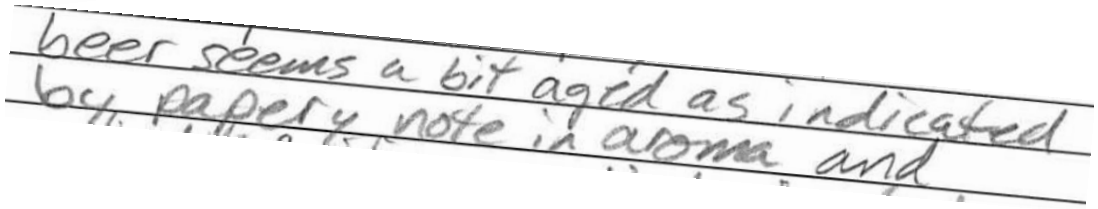
- Lots of early notes of oxidation
- Most beers judged (homebrew & commercial) show some signs of oxidation







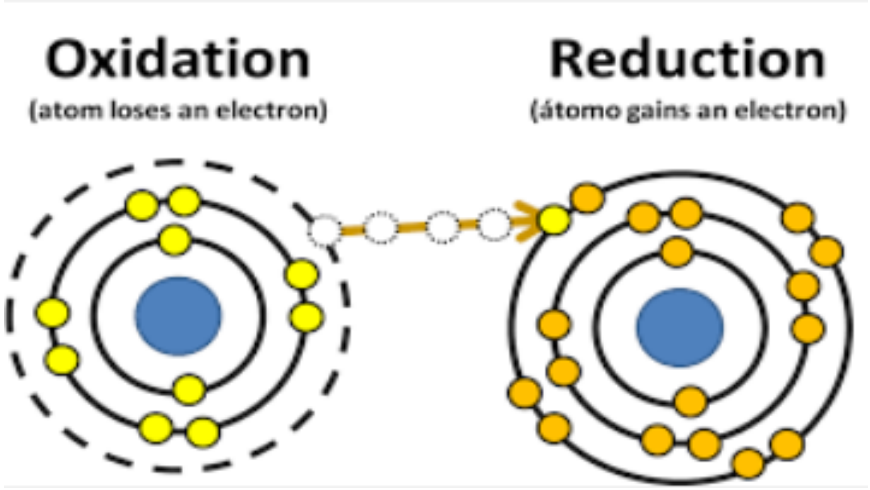


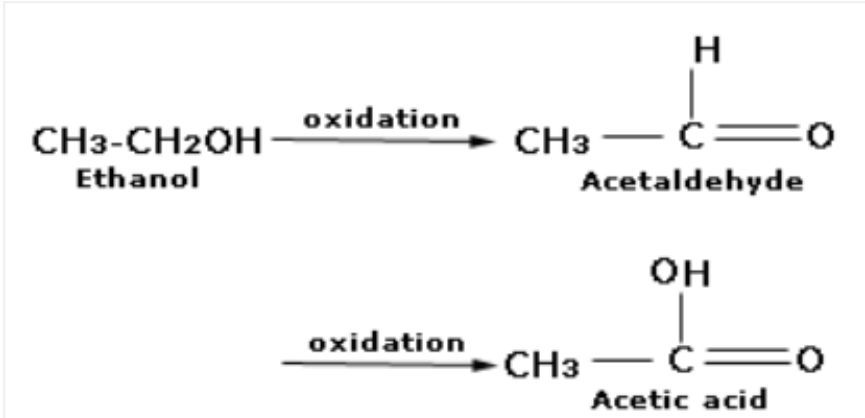


What is Oxidation?

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



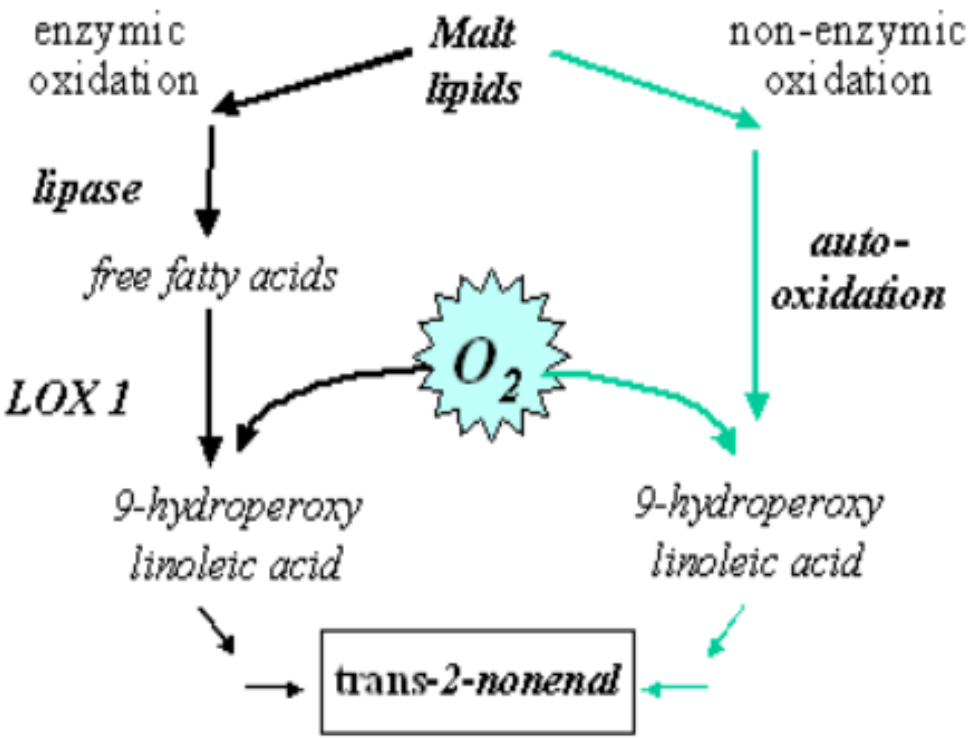


Oxygen & Oxidation

- **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-nonenal (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 threshhold about 0.1 ppb.
- Sulphites interact with trans-2-nonenal 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

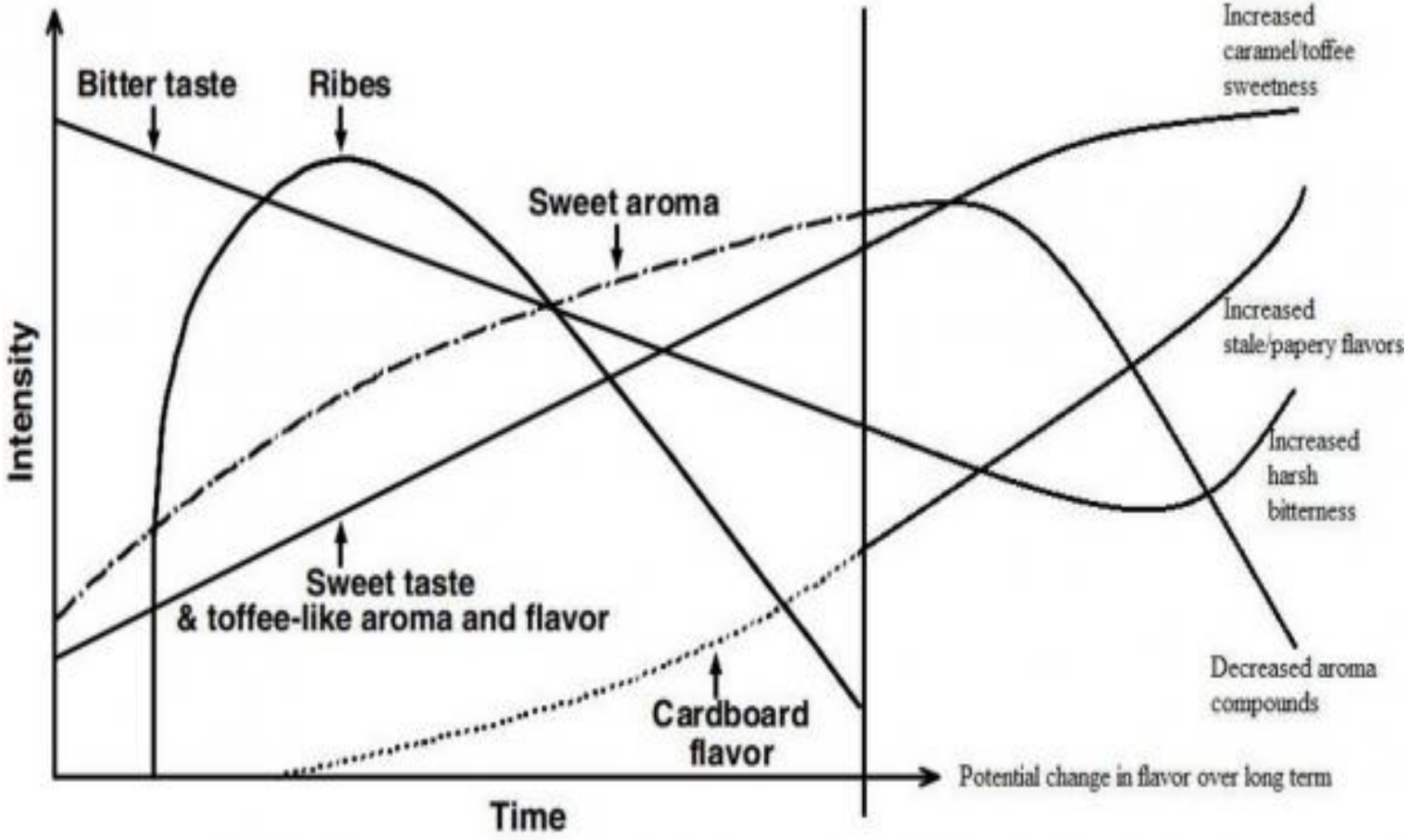


Fig. 1. Sensory changes during beer aging according to Dalgliesh (1977).

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

Temperature °C	0	5	10	15	20
O2 dissolved in water	14.5	12.7	11.2	10.0	9.9
O2 dissolved in 12% wort	11.6	10.4	9.3	8.3	7.4

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

	Days to Staling	
Headspace air (mL per 1/3 L)	**Storage at 86 °F (30 °C)**	**Storage at 43 °F (6 °C)**
0.5	60	120
1.0	40	100
1.5	20	80
2.0	5	70

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 CO_2
- Careful racking to avoid splashing
  - Starsan in top of auto-syphon to reduce bubbling
  - Rack with CO_2 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

Tank	O2 cc/l year
HDPE Bucket	220
Homebrew barrel	23
Class Carboy, 30cm vinyl immersion tube	0.31
Class Carboy, silicone stopper	17
Class Carboy, wood stopper	0.1

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 CO_2 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 CO_2

- There is no CO_2 blanket
- CO_2 will mix with time, currents
- Putting CO_2 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 CO_2 pressure.
- Still leaves residual O_2
  - Airspaces in lid/cap
  - O_2 in starsan comes out of solution
  - Krausen/Active fermentation

Kegging

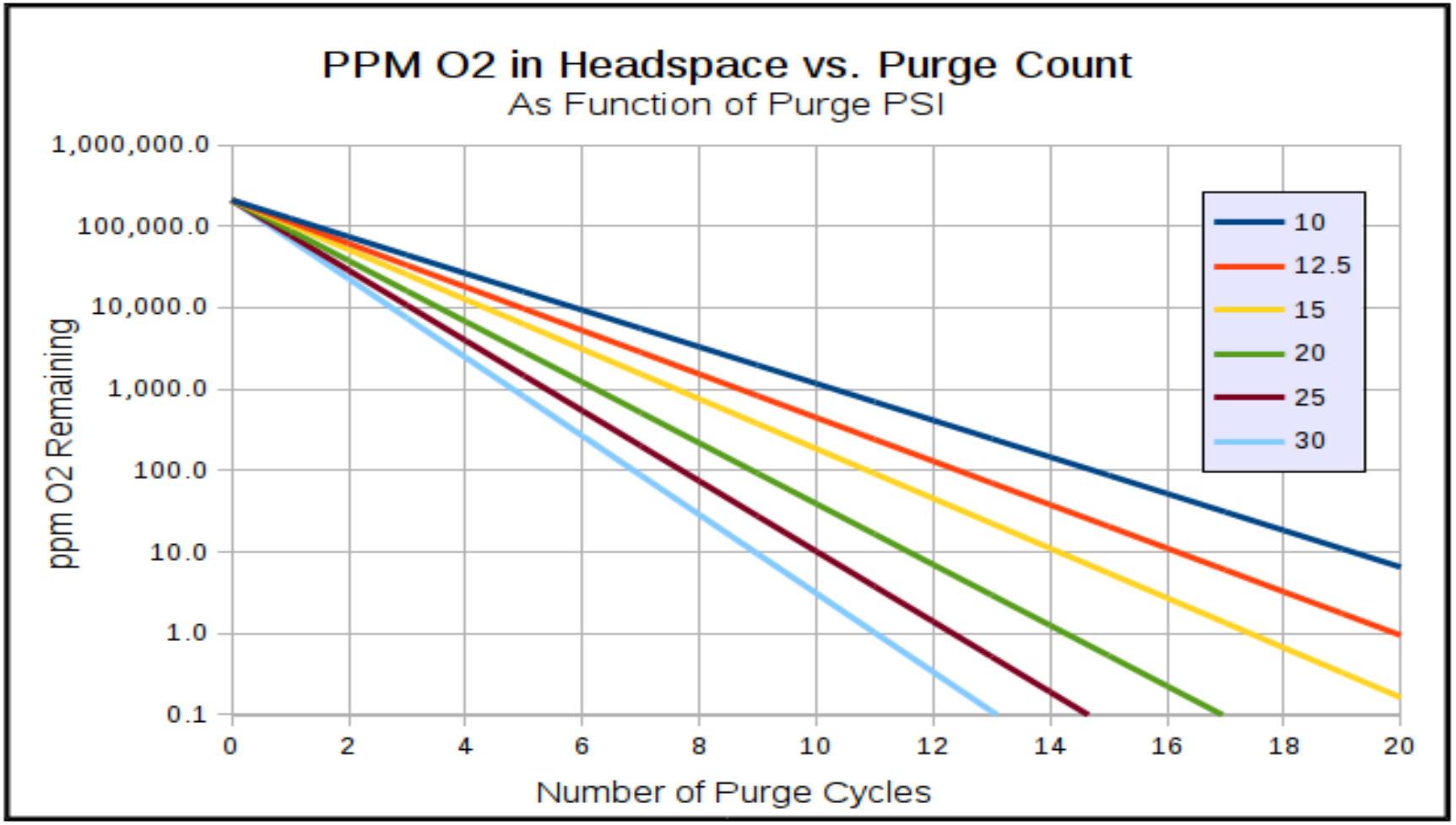
- Purge kegs completely
  - Fill with starsan/pre-boiled water then push out with CO_2
  - Uses less CO_2 than purging with PRV
  - Store sanitized, pressurized kegs
- Fill kegs through ‘out’ side
  - Add liquid QD to your auto-syphon or racking cane
  - Release pressure from PRV while racking

Purging the Keg – PRV Release

ppm O2 in Headspace after Purging						
Purge Cycles	Purge Pressure (psi)					
	10	12.5	15	20	25	30
0	210000.00	210000.00	210000.00	210000.00	210000.00	210000.00
1	124979.76	113492.65	103939.39	88962.54	77758.19	69060.40
2	74380.67	61336.10	51444.75	37687.30	28792.07	22711.14
3	44267.04	33148.55	25462.55	15965.51	10661.05	7468.76
4	26345.16	17914.84	12602.68	6763.49	3947.54	2456.17
5	15679.10	9681.92	6237.69	2865.22	1461.68	807.73
6	9331.29	5232.51	3087.34	1213.80	541.23	265.63
7	5553.44	2827.86	1528.08	514.20	200.40	87.36
8	3305.08	1528.29	756.32	217.83	74.21	28.73
9	1966.99	825.95	374.34	92.28	27.48	9.45
10	1170.64	446.38	185.28	39.09	10.17	3.11
11	696.70	241.24	91.70	16.56	3.77	1.02
12	414.63	130.38	45.39	7.02	1.39	0.34
13	246.77	70.46	22.47	2.97	0.52	0.11
14	146.86	38.08	11.12	1.26	0.19	0.04
15	87.40	20.58	5.50	0.53	0.07	0.01
16	52.02	11.12	2.72	0.23	0.03	0.00
17	30.96	6.01	1.35	0.10	0.01	0.00
18	18.42	3.25	0.67	0.04	0.00	0.00
19	10.96	1.76	0.33	0.02	0.00	0.00
20	6.53	0.95	0.16	0.01	0.00	0.00

Thanks to HomeBrewTalk member doug293cz for the chart

Purging the Keg – PRV Release

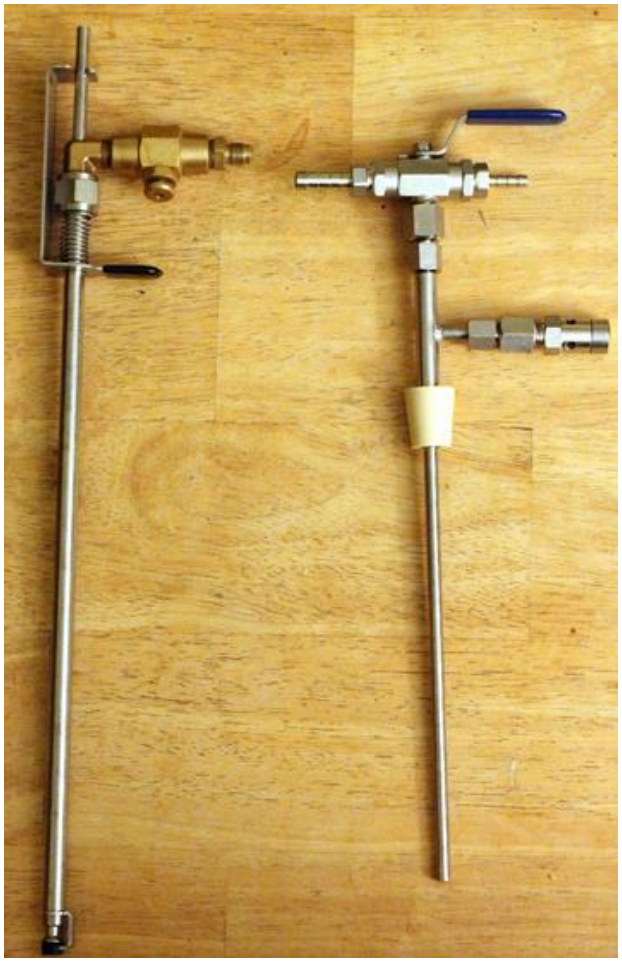


Thanks to HomeBrewTalk member doug293cz for the graph

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 CO_2 pressure to purged vessel
  - Cap on foam!
- Keep finished beer as cold as possible and drink fresh!
- How much oxidation is acceptable?


Questions

Thank you!

Brian Bergquist

president@fredhomebrew.org
http://fredhomebrew.org

11047 Pierson Dr. Ste. A
Fredericksburg, VA 22408
brian@thebrewshop.biz
http://thebrewshop.biz
540-479-2040