Effects of Hot Side Aeration of Wort, Mash & Sparge Water

JOHN ROZBORSKI

Hot Side Aeration

- **HSA - Hot Side Aeration**
- A generally accepted definition

The introduction of O2 into hot wort.

The O2 may bind with compounds in the wort, it is generally believed these oxidized compounds can break down over time and result in staling effects – namely off flavors and aromas.

The most common perception is that HSA can occur during the transfer of hot wort from the mash tun to the boil kettle

Which is why brewers use submerged hoses or feed lines to avoid cascading hot wort into the boil kettle. George Fix wrote in the Winter 1992 edition of Zymurgy magazine that Coors changed brewing equipment standards by implementing bottom feed lines to all of their boil kettles, and attributed this modification to the prevention of HSA and the desire to avoid staling.[1]

What is Staling?

The perceived degradation of beer over time, which is accelerated with thermal cycling.[2]

Two forms of staling:

- Increasing compounds
  - the formation of compounds typically associated with carbonyls
  - Common carbonyl compounds in beer are: Acetaldehyde, furfural, asstd methylpropanals and methylbutanals, and nonenal.[2]
- Decreasing compounds
  - the reduction of compounds, perhaps the most common is hop aromatics, which tend to diminish over time.

S. A Depraetere, et al, described their findings on the staling or aging of beers as following these sensory patterns:

“Beers become sweeter, less bitter, less fruity and hoppy. In addition, pungent taste increased, together with a complex aroma, consisting of solvent, papery/cardboard, ribes, Madeira, caramel and sulfuric ageing notes”[2]

These observations were made during an aging study on pilsners and ales.

Dark malt beers have staling flavors that can be different than those associated with pale beers. Some of the descriptors of staleness in dark or strong beers are Sherry-like, tomato, briny and black olives.

While enjoying a beautiful day of brewing I checked my sparge level and saw this…

Sparge water is quickly incorporated into the mash bed and then mixed into the wort. If this sparge water was highly aerated, could this "aerated sparge" also be capable of creating oxidized compounds that would lead to stale beer?

My conundrum:

If aerating hot wort is bad, couldn't a vigorous sparge also be bad?

If free O_2 binds with compounds in wort, when the wort is aerated, then shouldn't those same compounds bind with soluble O_2 present in sparge water that blends with the wort?

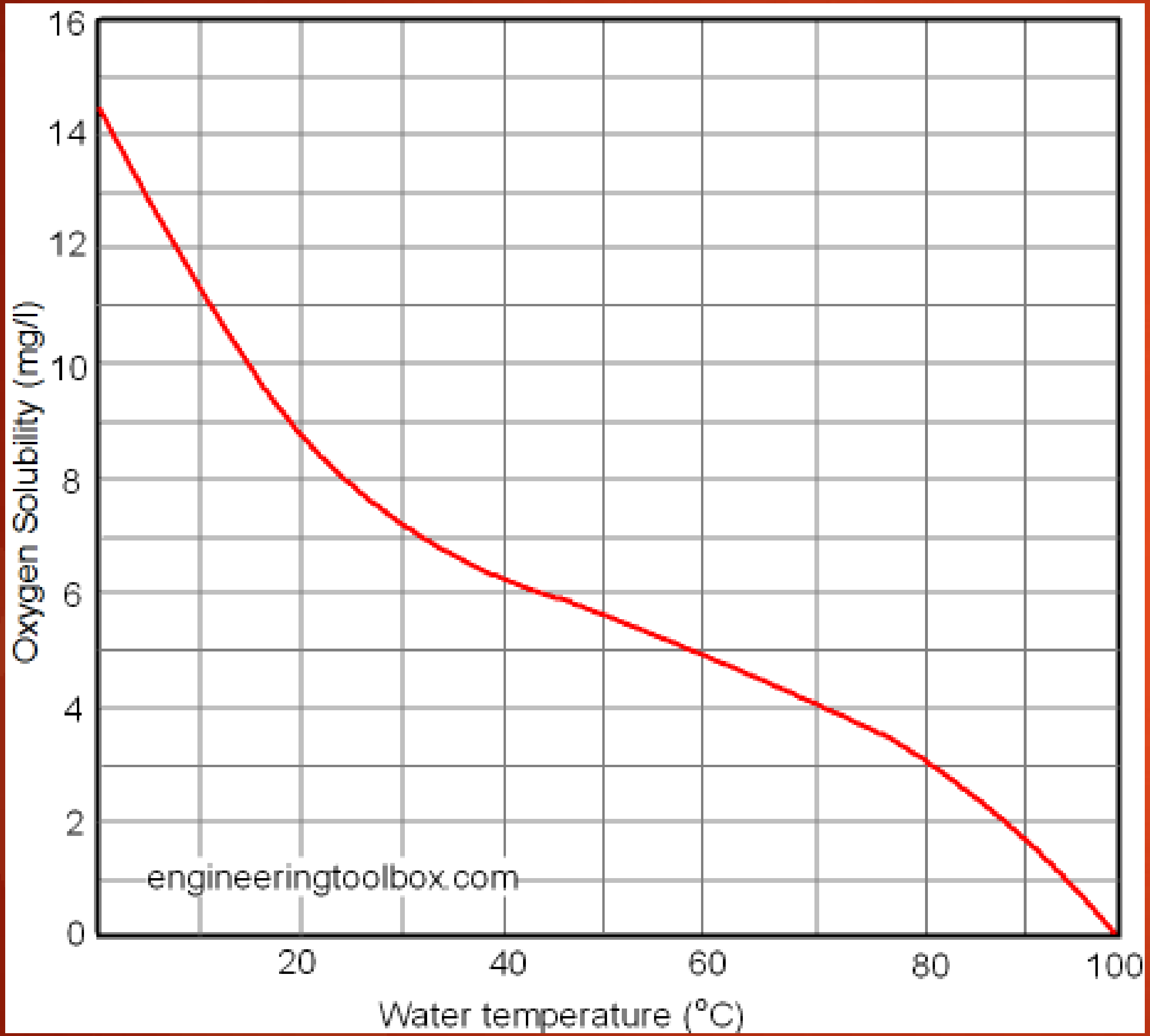
The Brew Community says:

Blogs, Forums, Friends& Fish

- HSA is real, Sparge aeration is not a problem.
- Neither HSA nor sparge aeration are problems.
- Don’t worry about it

Conflicting & confusing responses

Solubility of Oxygen - O_2 - in Water[3]



Important brewing temps:

50C step mash (5.7 mg/l)
65C single mash temp(4.5 mg/l)
75 C sparge water temps (3.6 mg/l)
100 C O2 is not soluble in water

Observation: O2 can be soluble in water, even at sparge temperatures.

Question: Can this level of O2 in Sparge water contribute to Oxidized compounds in the wort?

Stuck Mash = Stuck John

- The more I asked questions about HSA the more conflicting answers I received.
- During last year's AHA Conference in Philadelphia, I learned that the AHA was encouraging homebrewers to propose and perform research and experiments.
- I wrote a draft for the experiment, submitted it to the AHA* committee.
- While attending Bloatarians Beer & Sweat the next weekend, Roxanne Westendorf informed me that the experiment was approved
- The work needed to begin

*American Homebrewers Association, Research & Educational Fund Subcommittee (AHA R&EF)

The objective of my experiment was to brew multiple batches of an ESB, where I would control a single variable, infusing O2 into the sparge water, or into the wort preboil. The intent was to create extreme cases of potential oxidation.

I would also brew a third control batch, where I would be careful to avoid any aeration. The three batches would then be evaluated at specific time intervals after bottling.

The hope was to be able to observe specific and **significant** patterns of staling degradation. The evaluations were all to be double blind, and conducted by teams of BJCP judges.

The Experiment initial proposal:

My first draft, original experiment proposal included the following test batches:

1) Infusion of O2 into the wort preboil
   - intended to replicate cascading turbulent transfer of wort into the boil kettle

2) Infusion of O2 into the sparge water
   - intended to replicate aggressive shower head sparging (which was my typical process!)

3) Control batch

The Experiment as modified by the AHA R&EF:

1) Infusion of O_2 into the wort preboil
   - intended to replicate cascading turbulent transfer of wort into the boil kettle

2) Infusion of O_2 into the sparge water
   - intended to replicate aggressive shower head sparging (which was my typical process!)

3) Infusion of O_2 into a step mash during dough-in below 130F
   - Intended to activate an enzyme called lipoxygenase which can bind O_2 to lipids & melanoidans

4) Control batch

Low temp dough in oxidation : Lipoxygenase enzyme LOX

LOX is a naturally occurring enzyme that develops in the embryonic tissues of germinating barley. It appears that much of the LOX is converted into carbonyls and driven off during kilning.

However, LOX is still named as an undesirable enzyme active at the 100 to 130 F dough-in temperatures used in a step mash. At those temperatures LOX will catalyze the formation of hydroperoxides from unsaturated fatty acids. LOX denatures by saccharification temperature. Therefore, the potential for LOX oxidation is limited only to aeration of mash during the low temperature step.

If you are using the more common single temp mash in your brewing process, you do not have to worry about LOX oxidation issues. LOX enzymes do not survive single mash temperatures in the range of 145 to 155.[4]

The experimental batch with O2 infusion of the low temperature mash was intended to test if this LOX enzyme created carbonyl compounds which would lead to stale beer over time.

The Experiment Final Revision:

1) Infusion of O2 into the wort preboil
   - intended to replicate cascading turbulent transfer of wort into the boil kettle

2) Infusion of O2 into the sparge water
   - intended to replicate aggressive shower head sparging (which was my typical process!)

3) Infusion of O2 into the mash during dough-in below 130F
   - Intended to activate the enzyme called lipoxygenase which can bind O2 to lipids & melanoidans

4) **Infusion of O2 into the wort post boil**
   - Intended to replicate excessive aeration during whirlpooling, use of hopbacks, etc.

5) Control batch(s)

The experiment:

Batch / qty	O2 infusion	To simulate:	Objective
1A 5 G	Pre boil	Turbulent wort transfer to boil kettle	Experiment
1B 5 G	None	Good brewing practice	Control
2 10 G	sparge water	Highly aerated sparge water	Experiment
3A 5 G	Post boil	Turbulent whirlpooling, etc.	Experiment
3B 5 G	None	Good brewing practice	Control
4 10 G	119° F mash infusion	LOX reactions in aerated step mash	Experiment

Test evaluations:

The experiment was designed to evaluate all of the beers by teams of BJCP judges, using standard beer scoresheets at the following intervals:

Fresh: within 1 week of bottling

After 10 weeks

After 20 weeks

The Recipe: A simple ESB

10 G final batch size   some split batches (i.e. : two 5G batches)

12 G drawn off,
90 minutes boil

Single temp mash at 149   **one of the tests used a step mash**
5.2 PH modifier added to mash water

20#	2 row pale malt	
1.5#	Crystal 55	
1#	carapils dextrin malt	
4 oz.	Fuggle whole hops, 5.0 AA	60 minute addition

Whirlfloc & yeast nutrient   10 minute additions

Chilled wort was infused with 90 seconds of O2 prior to yeast addition
Yeast   WLP013 London Ale Yeast, with 2 L starters

O2 infusion method:

I used pure O2, flowing thru a .5 micron diffusion stone.

Pressure was set at approx. 10PSI, Oxygen was infused for a minimum of 120 seconds

Brewing and Bottling:

All of the beers were brewed consecutively over the Thanksgiving Day Holiday.

The beer was fermented in glass carboys, transferred after two weeks to secondary carboys, and kegged and force carbonated over Christmas holidays.

Bottling was done with a Blichmann Beer gun, and all bottles were purged with CO_2.

The beers were all capped with O_2 absorbing caps.

Notes to self:

Next time you schedule brewing four batches of beer consecutively, pick a warmer weekend, or do it indoors.

Field repair of pump.

It froze.

Verifying mash temperatures

My method to ensure aeration free sparging

O2 infusion in the 119F mash, LOX batch

Splitting ½ of the wort to the hot liquor tank so I can aerate pre boil.

Beginning the preboil O2 infusion

About 30 seconds of O2

Aerating wort. Pretty abusive potential oxidation going on here!

The preboil O2 infused wort had a massive hard break.

This kettle was approximately 40% full and had serious foaming issues.

40 plate counterflow chiller set-up, with a Blichmann thrumometer

This was a poorly conceived, not well thought out plan for dual boil kettles.

I forgot that my hot liquor tank didn't have a torpedo screen.

So I improvised this set-up to screen out the trub.

The plan worked.

Until the chill water return hose blew off and spewed water into my wort.

I lost a few G of this experimental split batch, making it necessary to rebrew.

The rebrew.

Using a different set-up. Still no torpedo screen in my hot liquor tank, but this time all of the hoses remained secure, and we strained right into the carboy, and skipped the stainless pot transfer step.

Uniform carbonation

The Pittsburgh based judge teams:

Tom Bosak (fl)
Mike Radford(bl)
Andy Weigal (br)
Lloyd Ruchlin (fr)

Results – Data:

Recap: The beers were bottled and assigned coded labels

The beers were evaluated by three teams of judges, 3 times.
Fresh
After 10 Weeks
After 20 Weeks

Evaluations were reviewed, collated and summarized
Aroma characteristics
Flavor Characteristics
Significant other notes and rankings where applicable.

These summarized data sheets were then analyzed for trends.

All of this data review and analysis was performed while the batch ID was still coded.
I did this so as to not skew my own interpretation of the subjective characteristics with anticipated bias.

Fresh

Baseline evaluation.

Significant correlation between teams.

Scores ranged from 26 to 36.

Very few to no significant flaws, occasional "slight" comments.*

The beers were average, decent representations of an ESB.

*one team received a bottle that had low levels of rubber, phenolic plastic. This appears to have been a contaminated bottle that was just beginning to turn. These results were discounted.

10 Week Summary

Overall, minimal degradation after 10 weeks.

Hop aroma and flavors diminished slightly to "no, slight, and low" the judges were still able to define the character of the hop aroma (earthy, flowery, spicy)

Fruit esters seemed to increase slightly overall. Pears, apples, cherry were predominant descriptors.

Flavors were sweet, toasty, caramel malt based with balanced bitterness.

Occasional slight off flavors were now being mentioned ("possible vegetal, slight paper)

The ranking of the beers was fairly stable, top ranked beers remained at or near the top, lower ranked beers remained at or near the bottom.

*One team did receive a highly infected bottle. This result was discarded.

20 Week summary:

Moderate to significant degradation.

Hop aromas diminished uniformly and were largely noted as “no” to “very low”.

Fruitiness increased, as did other esters and phenolics.

Sweetness seemed to increase.

Body and overall flavors seemed to generally thin out.

Some of the beers received scores and descriptions with high correlations. Others, not so much, even in the same team – with the same bottle sample.

Score disparity increased dramatically, both intra-team and between teams of judges. A single beer could receive both “best” and “worst” designations

Beer 1: O2 Preboil (shared mash with Control A)

Fresh: Rated Best by both teams
Light to low spicy, earthy hops,
Sweet caramel malt, spicy bitterness
Slight to V.L esters

10 week: Rated best by 1 team
Very low to low earthy, floral hops
Rich malt, caramel, toast, sweetness
Orange, pear, apple cherry, pineapple esters

20 week: Rated 2 best and 2worst ?!? (judges, not teams)
Very low to no hop
Sweet caramel malt
Very low to Low fruit esters, "slight staleness" described as musty, veggie, odd,

Evaluated to be sweeter, possibly under attenuated beer. Consistently ranked best beer.

Beer 2: Control A (shared mash with pre boil O2)

Fresh:
Low grainy malt, light caramel, light floral, earthy hops, no to low fruit esters
Malty, nutty, bready toasty, caramel malt, low to med. bitterness
No to low fruity esters

10 week:
No to low floral hop, low tasty, bready, sweet caramel aroma, slight fruit esters
Rich toasty sweet malt, L – M caramel, spicy hop.
Acidic orange, cidery, vegetal, possible DMS, slight paper

20 week: Mixed: two Best, one Worst (judges, not team)
No to very low hop, low to med caramel, toast, biscuit, slight sour/acidic aroma
Low sweet caramel malt, honey like, almost cloying, low bitterness
Low fruit, oxidized honey-like, papery, acidic, moderately stale

20 week review consistently had slight acidic/sour notes. Sweetness also seemed to have greatest increase noted.

Beer 3: O2 Post boil (shared mash with Control B)

Fresh: 2nd best by 1 team
light to medium spicy, earthy hops, low malt and caramel aroma
Low sweet malt, medium to assertive spicy bitterness
No to light esters

10 week:
No to low spicy, earthy hop aroma
Sweet malt, light caramel, lingering medium bitterness,
No to Slight fruit esters, orange, pear, apple, winey sweet.

20 week:
No to very low hop, slight fruit, light caramel and malt aroma
Low toasty malt, low caramel, low bitterness, lingering bitterness.
No to slight fruit. Cidery, watery, thin, slight phenolic, slight rubber, slight paper

Only beer to have moderate to assertive hop profile. Very low fruit esters throughout.
One of the top three in most reviews.

Beer 4: Control B (shared mash with O2 Post boil)

Fresh:
Slight to low earthy, floral hop, low malt, light caramel, fruity esters, cidery, apple notes
Low toast, grain, caramel flavor with low earthy spicy hops.
Moderate fruity esters, slight apple, slight acetaldehyde

10 week:
No to low spicy, earthy hop aroma
Sweet malt, light caramel, light bitterness,
Low fruit esters, orange, cherry, apple, winey, honey-like sweet, spicy peppery

20 week: two teams rated "worst"
No to very low hop, slight fruit, light caramel and malt aroma
Low toasty malt, low caramel, low bitterness.
Low fruit, watery, thin, slight paper, moderately stale

Generally had the lowest hop bitterness and aroma overall. Higher fruity esters throughout.

Beer 5: Step mash LOX test

Fresh: "thinnest"
No to light spicy, earthy hops, low malt and caramel aroma
Low to moderate slightly sweet malt, low bitterness
No esters

10 week: rated best by 1 team
No to very low hop aroma, slight vegetal
Slight caramel, medium bitterness,
No to Slight fruit esters, watery, thin, muted.

20 week: Rated 1 best and 1 worst (judges not teams)
No to very low hop
Low malt, low caramel, low to medium bitterness, thin
No fruit, to slight fruit. Slight rubbery, slight solvent, slight to sharp papery/cardboard.

Lowest of the fruit esters, universally described as thin. At 20 weeks, watery, cidery, solventy, alcoholy

Beer 6: O2 infused Sparge water

Fresh:
low earthy, spicy, floral hops, slight to low biscuit, malty caramel, no to low esters
Bready, toasty, sweet malt, slight caramel, low to moderate hop bitterness
No to very low esters, possible acetaldehyde

10 week: rated 2nd best by all
Light floral hops, low to med malt, w caramel, toffee, toast, grainy
Medium to rich malt, low caramel, toast, moderate bitterness
Slight tart/acidic, low fruit, slight stale, oxidized

20 week: Rated 2nd best and 2nd worst ?!?
No to low hop, low sweet toasty malt with low caramel, low fruit
Low sweet caramel, toast, low to moderate bitterness, med apple, pear, paper,
Slight to considerable staling, honey-like, oxidized almond, acetaldehyde

Fruit esters noticeably increased with age. Consistent comments about staling, paper, honey like oxidation at 20 weeks. Evenly split between those who liked and disliked at 20 weeks.

Fresh beer pics

20 week old beer pics

Step Mash	**Control (preboil)**	**O2 post boil**	**O2 sparge water**	**O2 preboil**	**Control (post boil)**

A review:

O2 preboil: Generally ranked as best beer, fresh, at 10 weeks and mixed at 20. sweetness and fruit esters increased at 20 weeks Shared mash with Control A

Control A: mixed results at 20 weeks, both best and worst. Consistent acidic/sour notes at 20 weeks. Shared mash with O2 preboil. Sweetness increased

O2 post boil: Only beer to have moderate to assertive hop profile. Very low fruit esters throughout. Ranked 2nd best fresh. At 20 weeks, it was described as cidery, papery, thin, phenolic. Shared mash with Control B.

Control B: Generally lowest hop aroma and hop bitterness overall. Higher fruit esters. Ranked worst in week 20 by two teams. Shared mash with O2 Post Boil.

Step Mash, LOX test. Generally considered thinnest, universally washed out, watery, also solventy, phenolic and alcohol warmth at 20 weeks. Lowest fruit esters through out the test

O2 sparge. Fruity esters noticeably increased with age. Uniformly ranked 2nd best at 10 weeks, mixed results at 20. Fairly consistent staling, paper, honey like sweetness at 20 weeks.

Analysis:

All beers exhibited diminished hop aroma and bitterness.

All beers exhibited characteristics of "Staleness" at the 20 week evaluation.

The "control batches" routinely scored at or lower than their respective "abused twin" batches.

The O2 preboil scored an average 6 pts. higher than it's control twin, and was rated best beer. The twin control batch developed a distinct very mild acidity, tang or sourness at 20 weeks.

The O2 post boil and the twin control batch had distinctly different flavor and aroma profiles. The O2 post boil batch was uniformly described as being assertively bitter with no to slight fruit esters, while the control batch was considered to be low bitterness, and higher fruit esters.

The LOX step mash was described as thin and watery. At 20 weeks it developed solventy, phenolic, alcohol like notes, in addition to staling attributes. Very low fruit esters

The aerated sparge batch was 3rd overall fresh, was universally the 2nd best at 10 weeks and had mixed reviews (both best and worst) at 20 weeks. Fairly consistent stale attributes at 20 weeks. It also showed increased fruit esters and sweetness descriptors as it aged.

Analysis:

One of the questions I have is whether we should be looking for a single attribute (i.e. papery) or a multitude of independent attributes to identify HSA oxidation. It would seem possible and likely that the introduction of pure O2 into different phases of the mash & brewing process would yield different potential reactions and different oxidized compounds. It would then make sense that each of the batches could present a different oxidized or reactive characteristic.

With that idea, it is possible that each of the experimental batches had a specific reaction. It would then be our responsibility to perform multiple experiments to see if we can replicate and validate consistent results. With single experiment data points, I can only offer anecdotal observations. (ie it happened once, it might be relevant!)

Under this assumption, from the results obtained, I have highlighted certain potential outcomes for validation (or nullification) in future testing.

Correlations between Aerated Sparge water and O2 pre boil

Similarities:
Both of these beers showed increased fruit esters with age.
Both had sweetness descriptors that increased.
Both had been judged to have slight to moderate staling attributes.

Differences:
The O2 Sparge beer was noted to be crisper.
The O2 Preboil was noted to be more flavorful.

These two beers had parallel results, particularly for the noted increased fruit esters and increased sweetness. Based upon these results it appears possible that Sparge Aeration and O2 preboil have similar oxidizing capability.

Contra indications
Control A greatest Sweetness increase noted
Control B had the highest fruity esters throughout.

Per Depraetere's study:

Staleness is associated with:
Increased sweetness.
Decrease in fruit esters

Her study was done on pilsners, and ales made from 100% barley.

It is possible that the recipes and yeasts she used may present different staling reactions than an ESB as they age.

Additional tests could be performed to attempt to replicate and validate that O2 infusion in ESB's both in sparge and pre boil conditions, correlates with increased sweetness and increased fruit esters with age staling.

Potential Oxidation and reaction for O2 Post Boil

The O2 Post Boil batch had a significantly higher hop bitterness than any of the other batches. It also had a moderately lower fruit ester rating, consistently with the judges.

It differed significantly in character from its mash twin Control B, which had muted hop bitterness and high fruit esters.

It is possible that the these differences might be attributable to the infusion of O2 Post Boil.

It is possible that the Post Boil O2 infusion some how reacted with the wort and hops to enhance the bitterness of the hop profile.

Hot Air Stripping by Anheuser Busch and Post Boil O2 infusion

Anheuser Busch uses a hot air stripper to remove undesired volatiles from the boiled and still hot wort. Per The Oxford Companion to Beer:

"The hot wort is streamed in a filmy layer on the inner surface of thin vertical tubes through which is blown hot, sterile air."[5]

This is called a laminar stripper, as the two fluids are flowing in counter directions.

It is easy to see similarities between Hot Air Stripping and Post Boil O2 infusion

This air stripping process reportedly is intended to remove sulfur and other volatile esters.

The results of the O2 Post boil infusion test revealed no to slight levels of fruit esters, and high assertive bittering relative to all of the other batches.

It is possible that the O2 infusion removed volatile esters that might contribute to fruit esters.

It is possible that O2 infusion reacted with the wort and hops to enhance the bitterness profile.

Potential Oxidation and reaction for LOX low temp mash

The LOX batch of beer presented exceptionally low fruit esters, relative to the rest of the test beers.

The LOX batch of beer also presented a consistent rating of cidery, thin, phenolic.

It is possible that the O2 infusion during the LOX active temperature range resulted in these two attributes

There were no control brews to compare against, and therefore I can not make a judgment about whether these two attributes (ie low esters, cidery, thin, phenolic) are specific reactions to the LOX enzymatic reaction or are more attributable to the step mash process, or some other variable.

The LOX beer was also judged to have stale attributes. But the description of them, and the intensity seemed to be comparable to the other brews. Nonenal (old paper, cardboard) typically associated with LOX reactions were only noted by two of the seven judges in the 20 week evaluation.[6]

Interpretation:

How do you determine if a characteristic is significant, and more importantly, if there causation, correlation, or if is an unrelated, isolated instance (anecdotal).

For example: Control A (shared mash with preboil wort) had nearly universal comments about slight acidity/sourness after 20 weeks. It is significant because it is the only beer that had ‘sour’comments, and the comments were very consistent. Everyone noted a slight sourness.

There is no correlation with Control B, nor with the shared mash beer. This result would have to be looked on very suspiciously. On the surface as a sole data point, it would be inappropriate to correlate Control ESB’s at 20 weeks with acidity.

Unless further testing proved that “control ESB’s” consistently evolved over time to have slight sour notes, then I would assume this result is anecdotal: a result that is not associated with this test, and is attributable to some other variable (wild bug contamination).

Experiment Variables:

Spilt batches:

1) the O2 infused wort preboil and Control A
2) the O2 infused wort post boil and Control B

The split batches tended to have higher OG's, deeper color and presumably more intense flavors profiles than their 10 G cousins. Which I attribute primarily to the following:

The 90 minute boil process drove off approx. 2 G of water per boil pot. A 12 g starting wort was reduced to 10 G, but the two 6 g split batches were reduced by the same 2G per boil kettle, resulting in a 4 G yield. Additional volume loss was noticed in the again duplicated hops & protein trub remaining in the bottom of the dual boil kettles.

Batch variables:

Ref: Low temp step mash:

A difficult long process.

The total mash time easily exceeded 2 hours because of the difficulties.

Extended time at protein rest is attributable to thin body and poor head retention.[6]

This batch attenuated down to 1.006,

The extended protein rest and the higher attenuation could explain the consensus characteristic of thin and watery, and possibly the 20 week evaluations which included alcoholy, solventy, phenolic, and cidery.

Batch Variables:

Ref: O2 Preboil and twin control batch.

Initial mash temp of 157, which was rapidly cooled to the 149 target.
Initial OG of 1.060 exceeded target of 1.052
Final OG was 1.016 versus, typical 1.01 (LOX batch attenuated down to 1.006

Beta Amylase enzyme rapidly denatures at 157. It is my conclusion that this brief initial temperature excursion partially disrupted the Beta Amylase enzyme resulting in a more dextrinous, less attenuable beer.

The higher OG is attributed to dual boil pots driving off additional water combined with possibly lower initial volume of wort

These two factors made for a sweeter, richer, more intense beer relative to the other test batches, which could account for the O2 preboil beer being rated best beer throughout the evaluations.

This does not explain why the O2 Preboil beer was judged superior to the shared mash twin control batch.

Recommendations for experiment improvements:

1) All batches must be same size: no split batches.

2) Excessive time & temperature variations in any portion of the process should invalidate that sample (i.e. too high strike temp)

3) Judges should be given a list of characteristics to rate on, with a numerical scale of intensity, this would provide a numerical data point for plotting statistics, etc.

4) Infected samples should be replaced to obtain usable evaluations.

5) Control step mash batches should be brewed to compare to the step mash LOX trial.

6) Doing forced aging (thermal cycling) to increase the potential differences between batches.

HSA counter arguments:

Charlie Bamforth wrote in his 2004 paper, *A Critical Control Point Analysis for Flavor Stability of Beer*, a counter argument as to why HSA may not be anything to worry about.

Briefly, he states that healthy yeast during the fermentation process is extraordinarily proficient at reducing complex carbonyl compounds which are attributed to cause staling. He makes the case that if you have healthy yeast and a vigorous fermentation:

"it is highly unlikely that any carbonyl (whether bound or free) produced upstream will survive into green beer"[8]

This paper by the way, explains myriad complex enzymatic and other methods of producing endless varieties and vast quantities of carbonyls in malt, mash and wort, that in one aside, are seemingly struck down as insignificant.

Conclusions

Does HSA occur in the 4 distinct tests?

All of the beers, experimental batches and controls, presented staling characteristics.

There was no definitive, overwhelming, smoking gun, data point that clearly pointed to HSA staling levels of intensity greater in the test beers versus the control batches.

The two most potentially significant observations from this experiment are:

1) the correlation of increased sweetness and fruit esters in the O2 preboil and Aerated Sparge tests, which suggests that similar oxidized reactions might be occurring in both O2 infusions.

2) The significant lower ester values and more assertive hop bitterness noted in the Postboil O2 infusion.

Additional testing would be required to replicate and validate these two observations.

Implications:

The implications of the first observation, if validated thru additional testing, would mean that all grain brewers should exercise caution to avoid excessive aeration of both the sparge water, and the hot wort as it is being transferred to the Boil kettle.

The implications of the second observation, could have potentially great implication, if validated thru additional testing.

Consider the potential benefits of O2 post boil infusions, providing brewers with enhanced hop utilization for bittering, and the removal of volatile esters. It is certainly possible that Anheuser Busch already recognizes this dual benefit in the production of their light American lagers, with their Hot Air Stripping process.

In the meantime, I leave you with the advice of my friend…

Make good beer,
keep it cold,
drink it fresh.

So stop thinkin' and start drinkin'!

References:

1) Fix, George. "The Detriments of Hot Side Aeration." *Zymurgy* Winter 1992: 34-40. Web.
2) Depraetere, Sofie A., et al. "The Influence of Wort Aeration and Yeast Preoxygenation on Beer Staling Processes." *Food Chemistry* 107 (2008): 242-49. Web. 08 May 2014.
3) "Solubility of Gases in Water." *Solubility of Gases in Water*. N.p., n.d. Web. 01 June 2014.
4) Bamforth, Charley W. "A Critical Control Point Analysis for Flavor Stability of Beer." *MBAA TQ* 41.2 (2004): 97-103. Web.
5) Oliver, Garrett. *The Oxford Companion to Beer*. New York: Oxford UP, 2012. 190. Print.
6) Palmer, John J. *How to Brew: Everything You Need to Know to Brew Beer Right the First Time*. Boulder, CO: Brewers Publications, 2006. 145, 146. Print.

Acknowledgements:

I would like to express deep gratitude to Roxanne Westendorf, for her faith, trust, guidance and support extended to me during this experiment process. Not only did she encourage me, she also provided background research papers, articles & podcast reference materials, and headed up a team of BJCP judges in Cincinnati that provided consistent and timely test evaluations

To John Palmer who also provided a slew of additional related research papers on LOX and related oxidation research.

To the volunteer BJCP judges, who devoted their time and expertise in evaluating these test beers: consistently, on time, with gracious and dedicated responses.   The Pittsburgh based teams: Mike Radford, Tom Bosak, Andy Weigel, Lloyd Ruchlin, The Cincinnati based team: Roxanne Westendorf, Rob Westendorf, Phil Meyer.
The Ad hoc judges, Brian Robbins, Joe Geil, David Harsh,

To the American Homebrewers Association, Research & Educational Fund Subcommittee

You made this possible. Thank you