METHODS OF THE LOW OXYGEN BREWHOUSE

A Summary of Key Process Points and Information Concerning Low Oxygen Brewing

"Success consists of going from failure to failure without loss of enthusiasm."

"To improve is to change; to be perfect is to change often."

WINSTON CHURCHILL

While Mr. Churchill's famous quotes do not specifically address Low Oxygen brewing methods, his insights in the above quotes could not have more relevance to this process. What we are trying to lay out for those who read this document is an uncluttered, unpretentious look at brewing commercial quality beer in the home brewery. What follows is a straightforward synopsis of the key process points, methods and equipment one can use to produce fantastic beer in your home. This means all beer! ***Your ales and lagers will benefit equally from these methods***.

We hope you not only enjoy the content, but utilize it as it is meant to be: ***in the brewhouse!***

PREREQUISITES

We assume that the following list of prerequisites contains steps that you currently follow or plan on following in the future. Don't view this list as a set of limiting factors but rather as an assessment of your current capability and a wish/goal list for future purchases! As you will see further on in this document, we will try and outline key points of departure from certain methods and offer alternatives wherever possible so as to give all brewers the advantage of a "step-wise" implementation of the Low Oxygen process.

Can you in the future, or do you currently, implement the following:

- Step mashing?
- Low oxygen infusion step mashing with consistent temperatures?
- Can you hold consistent mash temperatures in a single infusion mash?
- Have a method for rapidly chilling water and wort?

- Yeast starters? Storage and repitching of yeast slurry?
- Can you approximate yeast counts?
- Assure yeast health?
- Control/monitor fermentation temperature?
- Monitor fermentation progress (flavor, gravity, etc.)?
- Bulk store and monitor finished/packaged beer?
- Estimate and control pH?
- Do you have an accurate scale for measuring brewing salts?
- Can you condition your grain?

If you answered yes to, or plan on answering yes to, the above questions then you are ready for Low Oxygen brewing!

Notes on Dissolved Oxygen

It's important to note that controlling DO levels in your wort and finished beer yields certain results. Controlling DO levels in the mash will preserve the fresh malt flavors inherent in the grains themselves by guarding them against oxidation. From that point on you are protecting those flavors that were preserved in the mash tun. When we say "lingering" fresh malt flavors, we are talking about this preservation in the finished beer and beyond.

Controlling DO levels after the mash serves to protect these flavors further. Basically these flavors will persist for varying periods of time based on how you control DO after preserving them. This is why controlling the boil and controlling the DO levels in the cold side of the process is important.

What follows is a summary of key values related to DO content and mitigation:

- Tap/RO water can be saturated to ~8-12 ppm
- O_2 solubility is ~4-5 ppm at mash temperature
- Pre-boiling/yeast scavenging can reduce DO levels to ≤ ~0.5 ppm
- Pre-boiling alone does not provide ***active*** protection against DO
- Metabisulfite (NaMeta or KMeta, SMB or PMB) or the use of a pre-packaged or DIY "Trifecta" (Meta, AA and Gallotannins) alone ***does not*** provide sufficient margin
- Dough-in can add ~1-3 ppm DO
- Atmospheric diffusion rate of O_2 is ~1-2 ppm/hr
- < 1 ppm DO during hot side is desired
- < 0.5 ppm DO during hot side is ideal (provides margin)
- Copper, Brass and Aluminum can introduce potential for oxidation reactions
- Brewtan B may serve to mitigate these reactions (collective experience is showing this to be accurate)
- < 0.15 ppm DO during packaging is desired for maximum flavor stability

NOTES ON EQUIPMENT/PROCESS

Below is a simple list of areas of improvement in equipment and process:

- Eliminate splashing or unnecessary aeration
- Stir gently
- Eliminate Copper, Brass and Aluminum (if, and where, possible)
- If using these metals, Copper chillers seem to be the most widely used piece, Brewtan B or equivalent substances are proving themselves very useful in mitigating possible Fenton Reactions during the hot side process
- Ensure tight hose connections
- Employ Metabisulfite (NaMeta or KMeta, SMB or PMB) or the use of a pre-packaged or DIY "Trifecta" (Meta, AA and Gallotannins) as an active O_2 scavenger. A few notes on antioxidants:

  - **Potassium Metabisulfite** - Several brewing science texts and papers, Narziss' work in particular, point toward elevated levels of potassium being detrimental to certain enzymatic actions in the mash. Narziss specifies that keeping potassium levels under 10 ppm is optimal. This corresponds to ~30 ppm of KMeta. If this dose provides you with sufficient enough scavenging, then feel free to use KMeta. If not, you may want to consider NaMeta alone or in a "Trifecta" blend. Antioxin SBT utilizes KMeta in its blend.

  - **Sodium Metabisulfite** – When the original team members of the GBF first outlined the procedure for Low Oxygen brewing and specified the amounts of NaMeta one could use for active O_2 protection, it came with the caveat that one would have to adjust the value as they developed their system improvements and "tightened" everything up. This is still valid, although it may be worth revisiting dose rates here:

    ~~100 ppm~~ – This was the original "fullproof" dose rate. It assumed someone had made no system or process adjustments whatsoever, i.e. no capping, no reduction in agitation/stirring, etc. ***It is no longer recommended save for the brewers who have not made any other system or process alterations and require maximum active scavenging protection. Even so, we still warn against using such high a dose.***

    ~~50 ppm~~ – **This was the second dose recommended, but we feel this is still TOO HIGH**. We recommend you start much lower, using too large of a dose may cause undesirable sulfur in the finished beer. The best suggestion we can offer is to use Sulfite testing strips to run "diagnostic" testing on your system. Once you know your consumption you can tailor your dose more specifically to your equipment. *We would say it is essential not to exceed 50 ppm when brewing Ales, and ultimately, Ale brewers may need to go lower…*

    20-30 ppm – **This should be the starting dosage.** Once a brewer has implemented many of the steps shown below, i.e. mash capping, reduction in agitation, No-Sparge, etc., and has used either a DO meter or Sulfite testing strips to establish their system consumption, this value seems to be what most people are settling on. It also happens to be the stock dosing for Antioxin SBT and the most common "Trifecta" dosage for Meta. This is quickly becoming the most popular and most practical dose for those who have done diagnostics on their system and implemented a fair amount of the suggested changes. Ultimately this is going to be set using testing strips and/or sensory analysis. You want fresh malt flavors but not excess sulfur in the finished beer. Experiment with dosing in small increments until you find the sweet spot. You should be targeting **ZERO** sulfites after cooling the wort.

    5-10 ppm – This was the original recommended dose for those who are sparging. This is a value that should ultimately be determined through diagnostics. You will most likely not have to exceed 5-10 ppm for sparging, as the residuals in the mash should be enough to protect you during the sparge.

- **"Trifecta" and other Blends** – A popular method being utilized is a blend of known anitoxidants such as Sodium and Potassium Metabisulfite, Ascorbic Acid and Gallotannins/BTB. There are some notable blends, Antioxin SBT in particular, that have fixed percentages but ultimately the brewer can use the combination to tailor the specific type of protecvtion each chemical offers to their system. As a starting point, 45/45/10 can be used as percentages of Meta/AA/GT or BB respectively. Forum members at the German Brewing Forum have noted that certain "Dual" blends, like Meta/BTB or Meta/AA have worked well for them given specific beer styles, etc. There is quite a bit of latitude here but basing the blends around your Meta dose is a good idea. See our spreadsheet for a "trifecta" blending and dosing calculator (Standard or Metric). It is a good idea when using Antioxin SBT to add back a targeted amount of Brewtan B to the mash when you begin reducing the dose. Since the gallotannins in Antioxin SBT are a fixed percentage of the blend, by reducing the KMeta dosing you are also reducing your gallotannin dose. Custom "Trifecta" users need not worry about this, as they can set their Brewtan B dose accordingly.

- Underlet mash if possible to reduce dough-in DO
- Employ a mash cap
- Consider continuous recirculation (direct fire) or recirculation when infusing
- If recirculating, make sure return line is below liquid level to minimize aeration
- If recirculating, reduce flow at outlet (mechanically or electrically) to ~3-4 l/min
- Consider using a lauter cap (to limit atmospheric diffusion of O_2 when lautering)
- Consider No-Sparge mashing (full volume)
- If sparging, treat sparge water with Metabisulfite (NaMeta or KMeta, SMB or PMB) or the use of a pre-packaged or DIY "Trifecta" (Meta, AA and Gallotannins)
- Pitch yeast, then aerate
- Chill wort as rapidly as system allows
- Pitch enough healthy yeast (more on that later)
- Ensure proper keg purging
- Consider using biological acidification (Sauergut)

Grain Crushing

Grain crushing is very important in the brewing process. In a perfect world you would get an ideal, intact husk and a fully crushed interior. However we can only do the best we can. The goal of malt crushing is to crush the grains and keep the husk intact. There are a few ways to accomplish this.

- **Mills (2 roller and 3 roller versions) -** You will always get a better crush with a 3 roller mill, as you can set different gaps to help you. You certainly don't need a 3 roller mill though to get a good crush. Milling speed matters much more.

- **Milling speed (the slower the better...)** - The rate at which the grain goes though the mill is going to have a dramatic effect on the crush. You can dial in your mill speed much like taking your pulse: count your revolutions for 15 seconds and multiply that by 4 to get your RPM. Target and RPM value under 100.

You may want to explore grain conditioning as well to go along with your milling methods.

Here are some advantages that go along with grain conditioning:

- Allows for coarser crush
- Coarser crush improves lautering
- Coarser crush inhibits LOX
- Improves husk elasticity
- Produces undamaged husk
- Allows for tighter gap on mill
- Yield and attenuation increase
- Conversion efficiency increases
- Conversion duration decreases
- Preservation of husk can improve stability
- Crush as close to dough-in as possible
- Use 1-2% water by weight

If a brewer is unable to mill their own grains, i.e. you rely on the LHBS for this function, short of buying a mill, a potential procedure for use may be:

- Purchase your grains un-milled and ask the shop if they will allow you to condition the grain before they mill it.

  - ***If they agree***:
    1.) Condition the grain with 1-2% water by weight (treated with NaMeta/KMeta)
    2.) Allow shop owner to mill grain (or do it yourself if the shop permits)
    3.) Spray the grain with an additional 1% treated water and seal completely
    4.) Take this grain home (preferably on brewday) and use it as quickly as feasible

  - ***If they do not agree***:
    1.) Allow shop owner to mill grain (or do it yourself if the shop permits)
    2.) Spray the grain with 1-2% treated water and seal completely
    3.) Take this grain home (preferably on brewday) and use it as quickly as feasible

You want to limit the time between when the grain is milled and dough-in is conducted due to the activation of oxidative malt compounds and exposure to atmospheric oxygen. It takes as little as 15 minutes for crushed grain to start staling after contact with oxygen.

Always keep track of your crush: you don't want flour, and you don't want uncrushed kernels. After mashing, always check your mash tun for uncrushed kernels. Take note of how lautering proceeded, as well as the appearance of your pre-boil wort. You may need to alter these methods per the type of grains used.

BREWING WATER

Crafting your brewing water is an important consideration when using Low Oxygen brewing methods.

Let's take a look at some key points and observations:

- RO/Distilled water will yield best results
- Brewtan B may be useful if using tap water (limit oxidation reaction potential from copper/iron)
- Metabisulfite (NaMeta or KMeta, SMB or PMB) or the use of a pre-packaged or DIY "Trifecta" (Meta, AA and Gallotannins) provides active protection from DO
- It takes 5 ppm of Metabisulfite to scavenge 1 ppm O_2
- 100 ppm NaMeta has potential for 101 ppm SO_4
- 100 ppm KMeta has potential for 86 ppm SO_4
- 100 ppm NaMeta has potential for 24 ppm Na
- 100 ppm KMeta has potential for 35 ppm K
- Keep this in mind when planning profile
- For most styles, CaCl is sufficient to add Ca
- $CaSO_4$ can be used when higher sulfate levels are required (think pale ales) although high sulfate levels can contribute to the introduction of sulfides during fermentation
- $MgSO_4$ can be used to slightly boost SO_4 to balance Cl/SO_4 ratio
- Targeting 40-50 ppm Ca is useful
- Watch Na levels when adding $NaHCO_3$
- See Section Above for Metabisulfite dosing recommendations
- Reduce dose as you "tighten" system
- Consider using SO_4 test strips to evaluate your system and its Metabisulfite consumption
- Metabisulfite reduces pH by 0.1 per 100 ppm:

Dose Rate	**ΔpH**
100 ppm	0.1
80 ppm	0.08
75 ppm	0.075
60 ppm	0.06
50 ppm	0.05
40 ppm	0.04
25 ppm	0.025

(***Note***: This is accounted for in the Low O_2 Brewing Spreadsheet (Standard or Metric))

Recipe Formulation

Low Oxygen brewing will present the brewer with a very new and exciting palate from which to work off of when creating new recipes or revisiting old ones. Malt flavors will be new and exciting and hop flavors and aromas will be enhanced.

Rather than present a fully formed recipe, here are some of the high level considerations for recipe formulation in Low Oxygen brewing:

- Color reduction can be ≥ 25% (or ≤ 75% of color predicted by the Morey equation)
- More is definitely not more, it usually means a muddy beer
- Pilsner malt alone may lack depth
- Consider a blend of Pilsner/Pale malt starting at ~4-5 EBC
- Wort flavor can take on characteristics of certain food products: cereals, breads, honey, etc.
- Vienna and Munich malts blended with Pilsner can add undesirable flavor elements as less Metabisulfite (NaMeta/KMeta, SMB/PMB) is used (flavor intensity increases as system "tightness" increases)
- Consider blending Munich malts starting at ~17-18 EBC for beers like Dunkel, Marzen, etc.
- CaraHell can be a useful addition to beer like Helles, Export, etc.
- Higher EBC Caramalts such as Caramunich can be used successfully in low % in many beers
- Roasted malts such as Carafa Special can be used to add color in small percentages
- Roasted malts may need to be scaled back in recipes that traditionally call for larger % (think RIS)
- Sinamar is a very useful tool in matching color of commercial clones or darkening without adding flavor.
- It may be necessary to revisit old recipes and reconsider their construction
- Consider conducting a mini-mash when entertaining new malts or attempting to taste flavors before use

With regards to bitterness, hop schedules and IBU calculations:

- Hop flavor will possess more "presence" and "brightness" for lack of a better word
- Hop aroma will be enhanced
- Consider high alpha bittering hops for boil additions or use hop extract
- Save noble hops for FWH and late boil aroma additions
- If at all possible, try and limit hop trub in the kettle, as it may impart vegetal characteristics

Mashing

Mashing is one of the most important stages, if not the most important stage, of Low Oxygen brewing. Here you preserve phenolic malt compounds that would otherwise be oxidized upon dough-in due to the high DO content. It's important to stress this point: you *are not* ***creating*** a specific malt flavor here but ***preserving*** one that is inherent in the malt. Your job as brewer is to give the malt the conditions by which it can be mashed without being oxidized. Two distinct procedures can be used to prepare your de-oxygenated water and mash-in:

First let's outline the preparation and mashing process using ***pre-boil***:

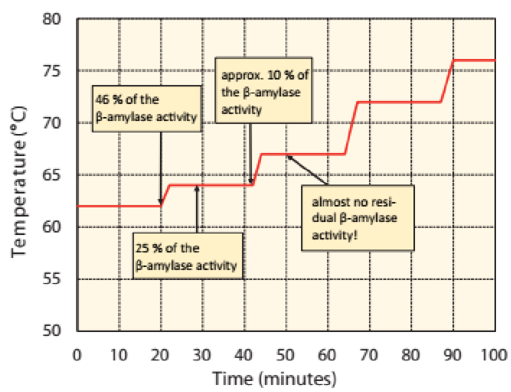
1.) Bring strike water to a vigorous boil for 5 minutes

2.) Chill the strike water as rapidly as possible to the desired strike temperature
3.) Dose strike water with Metabisulfite/"Trifecta" when temperature reaches 200 °F, then continue chilling
4.) Use the following dosing instructions to treat the strike water with the required amount of Metabisulfite:

Strike Water	Sparge Water
≤ 20-30 ppm	≤ 5-10 ppm

*NOTE – Reference the "Note on Equipment/Process" section for more detailed recommendations

5.) Add grain and brewing salts
6.) Underlet the treated strike water to the grains, if possible
7.) If adding water from above, or if lowering in a grain bag (single vessel), do it carefully so as to not aerate the water or splash
8.) Employ a mashing schedule that suits your system. If using direct fire/boiling water infusion, consider the Hochkurz schedule shown below. Consider using multiple β rest temperatures if possible, or pick a β rest that suits your needs. If direct fire is not possible and boiling water infusions too problematic, utilize a single infusion mash at your chosen temperature. Note that the β rest temperature and time may change according to the malt being used, most specifically in reference to the gelatinization temperature of the malt.



Now let's outline the preparation and mashing process using ***yeast scavenging***:

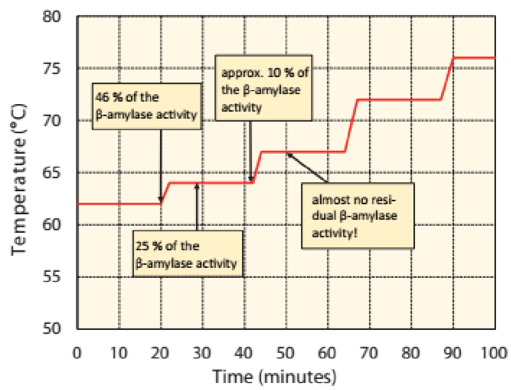
1.) Prepare a solution of dextrose and a dry bread yeast at a rate of twice your batch volume in grams (i.e. 5 * 2 = 10 grams each of dry bread yeast and dextrose)
2.) Ideal timing for dough-in following this treatment of strike water is between 2-3 hours
3.) Use the following dosing instructions to treat the strike water with the required amount of Metabisulfite:

Strike Water	Sparge Water
≤ 20-30 ppm	≤ 5-10 ppm

*NOTE – Reference the "Note on Equipment/Process" section for more detailed recommendations

4.) Mix the Metabisulfite or "Trifecta" into the water thoroughly and let rest for 5 minutes

5.) Add grain and brewing salts
6.) Heat water to strike temperature
7.) Underlet the treated strike water to the grains, if possible
8.) If adding water from above, or if lowering in a grain bag (single vessel), do it carefully so as to not aerate the water or splash
9.) Employ a mashing schedule that suits your system. If using direct fire/boiling water infusion, consider the Hochkurz schedule shown below. Consider using multiple β rest temperatures if possible, or pick a β rest that suits your needs. If direct fire is not possible and boiling water infusions too problematic, utilize a single infusion mash at your chosen temperature. Note that the β rest temperature and time may change according to the malt being used, most specifically in reference to the gelatinization temperature of the malt.



Now let's discuss some important points:

- Bottom filling via underletting is preferred
- Filling from above with a line below the grain bed should work also
- It is important to stir thoroughly but gently
- Continuous recirculation with direct fired MLT is beneficial
- Intermittent recirculation when infusion step mashing is beneficial (be mindful of temps)
- If using boiling water infusions without recirculation, stir gently
- You should notice lack of mash smells coming from the MLT
- ***Taste the wort. Well?***

Lautering

- Treat sparge water just as you would mash water (if sparging)
- Underlet if possible
- Sparge with care if not underletting: add water gently and stir gently
- Use the following dosing instructions to treat the sparge water with NaMeta:

Sparge Water
≤ 5-10 ppm

- If using FWH, add them while lautering to allow for enough steep time
- Consider a lauter cap to cover BK while lautering (limit atmospheric O_2)
- No-Sparge is recommended as the most efficient way to ensure you do not pickup up significant extra DO

BOILING

Boiling the wort created in the MLT adds an additional level of concern to the proceedings: It is important to control heat stress. This may come as a surprise to those who have read for years that vigorously boiling your wort is beneficial in many ways. Heat stress can serve to accelerate oxidation and affect the final flavor of the beer.

Some of the important aspects of wort boiling in the Low Oxygen regimen are:

- Control heat stress by limiting boil time to 60-70 minutes
- Consider partially opened BK lid (helps limit evaporation)
- Limit evaporation to 6-10% or less of boil volume
- Target a “simmer” rather than a robust boil
- Chill as rapidly as system allows to 5-6 °C
- Do not aerate/oxygenate until yeast has been pitched

PRIMARY FERMENTATION

Without going into a tremendous amount of detail here, let’s discuss, at a high level, some of the key factors and process points to primary fermentation for lagers and ales:

- Hot break MUST be removed
- Do not aerate/oxygenate wort until yeast has been pitched
- Active yeast is your friend and its presence before aeration/oxygenation ensures O_2 scavenging
- Pitching rates for cold fermentation – 1.6-2.5 x 10^6 cells/ml/°P
- Ensure yeast is well mixed
- O_2 or sterile air added to ~ 8 ppm DO
- Diacetyl/maturation rest should be unnecessary given the cold fermentation and high pitching rate
- The same considerations above apply, with the noticeable exception of reduced pitching rates
- Pitching rates for ale fermentation – 0.75-1.5 x 10^6 cells/ml/°P

A simple fermentation schedule for lagers (ale fermentation should proceed as normal):

1.) Cool wort to 5-6 °C (pitching temperature)
2.) Add yeast and aerate/oxygenate wort
3.) Allow beer to rise to 8 °C (over 48 hours)
4.) Hold at 8-9 °C
5.) If spunding: target 1% remaining extract prior to transfer (or use Low O2 spreadsheet calculator)
6.) If keg/bottle conditioning: Ferment to final gravity and use sugar/speise
7.) Utilize a Fast Fermentation Test (FFT) to accurate predict gravity (pull sample of fermenting beer for FFT)

Spunding and Closed Transfers

Now that you have produced Low Oxygen wort and transferred it to your fermenter, you essentially begin the next phase of flavor protection. Here is where implementing a phased approach to Low Oxygen brewing will yield you varying results. As important as it is to preserve the malt flavors in the MLT and through the boil, it is equally important for flavor longevity and stability to treat this fermenting beer, and ultimately the finished beer, with great care. The duration in which the Low Oxygen malt flavors will persist ("linger") in the packaging vessels is ultimately dependent on the cold side O_2 management you practice. Spunding and using natural carbonation captured from the fermentation of remaining extract is the preferred way of finishing the beer but as we will see in the packaging section, other methods for packaging and serving Low Oxygen beer exist and are viable alternatives. It should be noted here that minimizing trub from wort production and boiling serves as a valuable input to these later stages. The clearer the beer that goes into the fermenter the better. Break material exclusion in these stages will help speed up lagering and enhance and reinforce flavor stability of the final product.

Here is a simple method for transferring to a spunding vessel:

1.) Clean the receiving vessel and fill to the brim (may require a shortening of the gas dip tube) with a low oxygen sanitizer such as saniclean or iodophor
2.) Push the entire volume of sanitizer out of the keg with CO_2
3.) Utilize a closed transfer from fermentation vessel to receiving vessel:

For Keg to Keg transfer:

- Jumper liquid out posts
- Jumper gas in posts

For Traditional Fermenter to Keg:

- Jumper fermenter output to Keg liquid out
- Jumper blowoff to Keg gas in post

4.) Close receiving vessel and attach spunding assembly
5.) Set spunding assembly to desired pressure setting (start with 0.8 bar)

Allow the beer to finish fermentation in this vessel, checking gravity at various intervals in between.

Lagering and Packaging

Lagering takes place in the spunding vessel after transfer. Depending on the break exclusion routine you use, lagering times can be significantly reduced and this phase shortened accordingly. It is important to sample the beer as it progresses through the lagering process. Carrying over enough yeast to provide natural carbonation through fermentation of the remaining extract is another important part of this stage. Packaging can be carried out using a number of methods and packaging vessels:

Kegging:

1.) Dispense from Spunding/Lagering vessel or;
2.) Ferment to final gravity in fermentation vessel and use speise/sugar priming in serving vessel

Bottling:

1.) "Bottle Spunding", i.e. bottling right off of fermenter or;
2.) Ferment to final gravity and use speise/sugar priming dosed inline at bottling or;
3.) Use a counter pressure bottle filler and package of the serving keg

Canning:

Canning is the largest investment one could make in packaging technology. It is not without some hesitation that people brewing at home would even consider. Fortunately, if you do decide to shell out the capital for a unit like the Oktober MK16 (as shown in our video), we have you covered as far as a sound method for packaging your beer in cans is concerned.

One of the key things to keep in mind when packaging is that while many useful anti-oxidant substances can be used when packaging, nothing supplants active yeast and its ability to naturally scavenge O_2.

Conclusions

The goal of this paper is to allow the homebrewer, with varying levels of experience, to adapt to and incorporate the basic concepts of Low Oxygen brewing into their personal brewhouse and experience the wonderful flavors of this style of brewing. We hope that this uncluttered approach is useful in untangling some of the information that exists on the subject.

This document has been constructed to be interactive with the content on lowoxygenbrewing.com. You'll see many links peppered throughout the document that link to more detailed information on individual subjects discussed at a high level here. It is our hope that this overview provides the basics for the process and the links enhance the topics so that brewers can use Low Oxygen methods without being burdened with the “heavy lifting”.

Low Oxygen brewing does not have to be hard and we are here to help you get on your way!

References

Low Oxygen Brewing References Page

Web Version of this document

Archival References Database