MBAA TQ vol. 57, no. 1 • 2020 • pp. 19–21

Managing Dissolved Oxygen in the Brewery

Audrey Skinner

Imbibe Solutions, Charlottesville, VA 22902, U.S.A.

ABSTRACT

The shelf life of a beer can be impacted by many variables, but one of the biggest influences across breweries, beer styles, and production methods is oxygen exposure. Oxidation can impart many undesirable qualities in a beer, and it does not take a lot of contact with air to start these reactions. Methods brewers can employ to reduce potential oxygen pickup around the brewery are discussed. Comparisons of popular portable oxygen meters and package piercers currently in the market are also presented.

Oxygen reacts quickly, faster than you can blink. It binds to free molecules in an instant and then reacts with other compounds over time. These fast and slow reactions are what make it such a large threat to beer stability. Oxygen can infiltrate a product even with minimal exposure, and the sensory effects may not be immediately perceptible.

If a significant amount of oxygen is introduced, the beer may start to show preliminary signs of aging: the aroma may dull, the color may darken, and the flavors may become lackluster, sweeter, and more malt forward. Over time, these characteristics will increase and a cardboard or wet paper taste and aroma will develop. Even just a little oxygen ingress will speed up the staling qualities, but by the time they are apparent, the product will likely have been released to distributors and the public.

Dry-hopped beers display the most noticeable effects because they are the most delicate, chemically speaking. Aroma is perceived when odorous compounds are volatile and can reach the olfactory system. Dry-hopped beers rely heavily on these volatile compounds; hence, a common description for strongly dry-hopped IPAs is "a punch in the face." When oxygen is introduced, these volatile compounds are chemically altered. They can either take on new odors, which sit above or below the sensory perception threshold, or become nonvolatile (i.e., odorless). Altering or taking away the volatile compounds from a beer that heavily relies on them will drastically affect the way it is perceived.

Alternatively, malt-forward, high-alcohol beers may benefit from slight oxygen exposure, such as they would get through barrel aging. The oxidation reactions promote the creation of more stable flavor and aroma compounds that effectively soften and meld the flavors in a way many find pleasant. However, even aged beers have a limit on the amount of oxygen exposure they can tolerate before flavor and aroma compounds are negatively altered. All other beer styles fall somewhere in between these extremes of negative and positive oxidation impact.

Audrey Reid is a gastronomical chemist and owner of Imbibe Solutions, which provides quality control testing services for craft brewers.

E-mail: audrey@imbibe-solutions.com

https://doi.org/10.1094/TQ-57-1-0114-01

Reducing Oxygen Pickup

Most concerns about oxygen exposure start on the cold side of production after fermentation, and it is in the best interest of the brewer to monitor and limit ingress as much as possible. Common culprits in the cellar to be aware of include:

- Sample ports: Any time a new sample port is attached, an air bubble is trapped between the tank valve and the sample valve. When the tank valve is opened, that air bubble goes into the beer. To prevent accidental oxygen introduction, leave the sample valve partly open while opening the tank valve to push the air bubble out. Then close the sample valve and proceed.
- Transfer hoses: Transfer hoses are usually connected at both ends, trapping air or oxidative sanitizer inside them. Unless multiple gallons of the initial beer passing through the hose will be dumped, it is best to first purge the line with CO_2. To do so, hook up a stainless steel T-fitting to either end of the hose and use the free port to push CO_2 through the lower end while expelling air/CO_2 out the higher end. The amount of time it will take to fully purge the line will depend on the length of the line. For shorter lines (about 10 ft long), a 10 min, low-pressure (5 psi) purge should be sufficient.
- Pumps: Pumps are notorious for oxygen pickup. Make sure all seals are replaced quarterly and are secure during use. Loose or overtightened connections can allow for air ingress.
- Bright tanks: Bright tanks must be purged before they are filled. This cannot be stressed enough. An unpurged tank is full of air, ready to interact with any beer that is pumped in. The purge should also be conducted at a low pressure (5 psi is recommended) for a long period of time (3–4 h for a 30 barrel tank, or roughly 1 h per 10 barrels). Low pressure, slow flow, and sufficient time are very important and should not be ignored. High pressures cause turbulence within the tank, which will mix the pure CO_2 with air, preventing the air from being fully expelled. Short purges will not fully purge the tank, and the air and CO_2 will blend if allowed to stand. The theory of reducing CO_2 use by making a buffer layer and then filling *may* work *if* purge and fill happen on the same day, if the purge is very slow, and if the purge is long enough to create a buffer that is multiple feet thick. At least one third of the tank height is a good rule of thumb (estimated by the rule of 1 h per 10 barrels).

If the buffer layer is too thin, not pure enough, or allowed to sit before filling, it will be ineffective.

These concepts also apply to filling the tank. Initial flow should be slow to prevent fountaining, which will disturb the gas above. This is extremely important if the buffer layer method is being utilized. It is also good practice for fully purged tanks on the off chance there is still oxygen present. Moreover, it is gentler on the beer. After a few barrels have been introduced, the fill speed can be increased.

- Packaging line: Different brands and styles of packaging lines operate with their own methods and quirks. However, there are a few universal techniques that can be applied to reduce dissolved oxygen pickup. The terminology used below will be specific to canning lines, but similar concepts can be found on bottling lines.
    - The first area that should be examined is the foam cap. The foam cap is the only barrier between the beer and oxygen between filling and lid application. It is important that the beer foams enough to make a cap that is pushed off when the lid drops (Fig. 1). By pushing the foam off, the beer that came in contact with the oxygen will be removed from the final product. There is a balance between creating enough foam to protect the beer and getting too much breakout, such that the finished package is underfilled. The style of beer, its packaging temperature, and its carbonation level will all have significant influence on foam production. For example, dry-hopped beers will break out more easily than a lager, and colder beers will not break out as much as warmer beers. The right combination of carbonation, style, and temperature will be different for each brand, and it will require trial and error to find the right level of foam produced. Unfortunately, a combination that works on one line may not work on another, so there is no universally correct answer.
        - Play with the settings on the machine. The quick burst function may prove useful in creating foam.

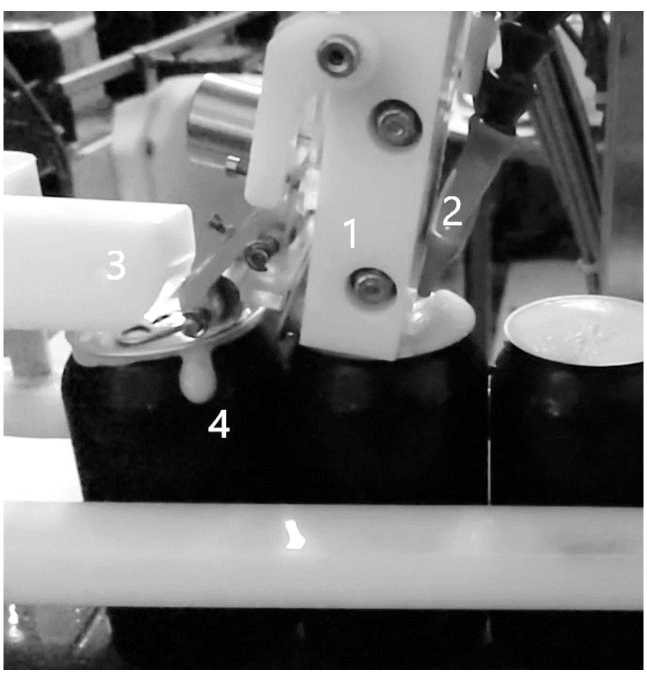

Figure 1. A canning line: 1 = lid drop; 2 = pre-lid-drop CO_2 purge; 3 = lid tapper; and 4 = foam pushed out from under the lid.

    - Make sure the package is being purged with CO_2 before filling.
    - Use a pre-lid-drop CO_2 purge. The pressure should be just high enough to skim the foam off the top of the can but not strong enough to send foam flying into the air.
    - Once the lid has dropped onto the can it needs to be tapped down. Some lines have built-in wheels or "hockey skates" that fulfill this function.
    - Check and replace all soft parts frequently. The amount of use the line sees will dictate that frequency, but it should never be longer than 1 year before they are replaced.
    - As full as possible is best. Think quality over quantity—it is better to lose some beer in the process than to put an oxidized beer out to the market.

The goal is to have less than 50 ppb (µg/L) of oxygen present in the final package. There is a caveat, however. Since oxygen reacts so quickly, the measurement process must be started on packages as soon as they come off the canning or bottling line. If the package is allowed to sit before starting the measuring process, the reading will be artificially low because the oxygen has had a chance to bind with other compounds and will not be detectable. That also means that the measurement is only accounting for the most recent oxygen additions. If the beer was exposed to oxygen in the cellar before packaging, it is likely that the oxygen is already bound and undetectable. This is why it is important to stay on top of the best practices mentioned, even if the final package has a low measurement.

Breweries with the capability to measure dissolved oxygen will likely do so in multiple places, with either an in-line unit or a portable unit. Doing so allows them the opportunity to identify where oxygen ingress occurs so they can address it. They also likely monitor the efficacy of bright tank purges. Many meters can detect oxygen in gas as well as liquid. As mentioned earlier, purging the bright tank is the most important step in reducing oxygen pickup. An unpurged tank is the quickest way to expose the entire batch. Even kegs, which often avoid complex packaging lines, will exhibit severe amounts of oxidation.

There are multiple options in the market for monitoring dissolved oxygen. Listed below are a few portable meters that can be connected to either a bright tank, transfer line, keg, or package piercing device. There are also in-line meters and benchtop meters, but they are limited in their testing ability to one area of production. These are most beneficial to larger breweries that can afford to have and run both.

Note: When measuring dissolved oxygen or total package oxygen, the first step in the measuring process is to shake the can or bottle before piercing. This will equalize the oxygen in the headspace with the oxygen in solution to provide an accurate reading. A minimum of 3 min is recommended. If a shaker table is unavailable, put those triceps to work!

Equipment

Portable Meters

- CBoxQC At-line by Anton Paar
    - Price range: $20,000
    - Technology: optical oxygen sensor
    - Analysis range: 0–4,000 ppb
    - Repeatability: ±2 ppb
    - Reproducibility: ±4 ppb if in the range of 0–1,000 ppb; ±10 ppb if within 1,000–2,000 ppb; and ±20 ppb if within 2,000–4,000 ppb
    - Measurement time: 90 s

  - Pros: also measures CO_2 via multiple volume expansion; low maintenance; can transfer data to a computer spreadsheet
  - Cons: expensive
- Orbisphere 3100 Portable Oxygen Analyzer by Hach
  - Price range: $12,000
  - Technology: optical oxygen sensor
  - Analysis range: 0.6–2,000 ppb
  - Accuracy: ±0.8 ppb or 2%, whichever is greater
  - Repeatability: ±0.4 ppb or 1%, whichever is greater
  - Measurement time: 20–75 s
  - Pros: low maintenance; optional sensor with a larger analysis range
  - Cons: does not measure carbonation
- Haffmans Portable Optical CO_2/O_2 Meter C-DGM (AKA Gehaltemeter) by Pentair
  - Price range: $20,000
  - Technology: optical oxygen sensor
  - Analysis range: 0–2,000 ppb
  - Accuracy: ±1 ppb + 2% m.v. at 20°C
  - Measurement time: 120 s
  - Pros: able to measure CO_2 using Henry's law of gas/liquid equilibrium in a closed system; capable of continuous O_2 measurement; can transfer data to a computer spreadsheet
  - Cons: high maintenance; expensive
- Beverly DO Meter by Hamilton
  - Price range: $7,000
  - Technology: optical oxygen sensor
  - Analysis range: 4–25,000 ppb
  - Accuracy: 40 ± 7 ppb at 25°C
  - Measurement time: 1–3 min
  - Pros: high measuring range; long-lasting battery
  - Cons: cannot measure carbonation; low accuracy at low levels

Piercers

- Special Piercing Device for DO Meters by Zahm and Nagel
  - Price range: $700–$1,000, depending on required adapter
  - Container capabilities: up to 1 L
  - Pros: price; portability; variety of adapters for various DO meters
  - Cons: no explosion shield
- PFD Filling Device by Anton Paar
  - Price range: $5,500
  - Container capabilities: up to 0.5 L cans, 1 L glass bottles, or 3 L PET bottles
  - Pros: explosion safety shield; heavy, stable base
  - Cons: not easily portable; may require an adapter if not used with Anton Paar products
- Haffmans Inpack Sampling Device (ISD) by Pentair
  - Price range: $4,500
  - Allowed container height: 2–14 inches
  - Pros: portable
  - Cons: price for simplicity of device; may require an adapter if not used with Pentair products

Summary

Breweries of all sizes should be highly aware of the consequences of oxygen introduction to their products. Whether or not the oxygen levels can be measured, it is important to follow good practices that will reduce pickup. It does not take much for oxygen to have a damaging impact; the difference can be between a shelf life of 2 months and a shelf life of 6 months.

Extending the shelf life of a brand will keep customers returning because they know they are buying a reliable product, that the bottle they drink this week will be the same as the bottle they drink next week. Dull, darkened, and lackluster beers do not keep customers. A little proactivity toward defending a product from oxygen exposure will go a long way.

LINKS TO PRODUCT INFORMATION

- Anton Paar: https://www.anton-paar.com/
- Hach: https://www.hach.com/
- Hamilton: https://www.hamiltoncompany.com/
- Pentair: https://foodandbeverage.pentair.com/
- Zahm and Nagel: https://www.zahmnagel.com/

REFERENCES

1. Reid, A. Minimizing Dissolved Oxygen Pick Up Around the Brewery. MBAA Mid-Atlantic District Meeting, 4 November 2017, Green Flash Brewing Company, Virginia Beach, VA. Research Presentation.
2. Shellhammer, T., et al. Beer Quality and Analysis Series: Microbiology and Beer Analysis | Quality Assurance | Brewery and Hop Farm Tour, 13 May to 14 June 2019, Oregon State University, Corvallis, OR. Course Series.