OXYGEN CONTROL IN MICROBREWERIES

IBA QUALITY & TECHNICAL GROUP

INDEPENDENT BREWERS ASSOCIATION

1. WHAT IS DO AND HOW DOES IT AFFECT THE QUALITY OF BEER?

Dissolved Oxygen, the enemy of beer due to its detrimental impact on haze and flavour stability. Brewers go to great lengths to ensure that the right quantity of Oxygen is added to wort to ensure the correct yeast growth for active fermentation however post fermentation it is ideal to prevent O_2 ingress all together.

Oxygen is chemically highly reactive and combines with almost all other elements resulting in what is called oxidation. Oxidation is the main contributor to beer staling.

It is thought that oxygen is involved in oxidation reactions as reactive oxygen species (ROS), some of which are free radicals, generated as below:

$$O_2 \xrightarrow{e^-} O_2^{\bullet -} \xrightarrow{e^-} H_2O_2 \xrightarrow{e^-} {}^{\bullet}OH \xrightarrow{e^-} H_2O$$

Superoxide Free Radical — Hydrogen Peroxide — Hydroxyl Free Radical

Lipids derived from Malt are oxidized to a range of oxidized compounds that breakdown during the brewing process or in packaging to form aldehydes. The aldehyde trans-2-nonenal is noted for its cardboard/papery off flavours.

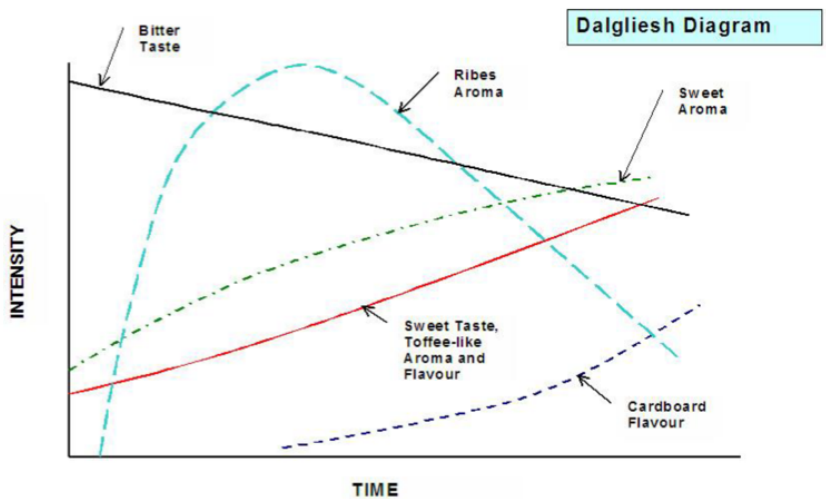
Melanoidins formed during wort boiling from a combination of amino acids and sugars. Melanoidins can participate in oxidation reactions to form aldehydes from their corresponding higher alcohols.

The oxidation of alpha and beta acids in hops form rancid and cheesy characters.

Oxidation of polyphenols leads to accelerated chill and permanent haze formation as well as an increase of beer astringency and beer colour.

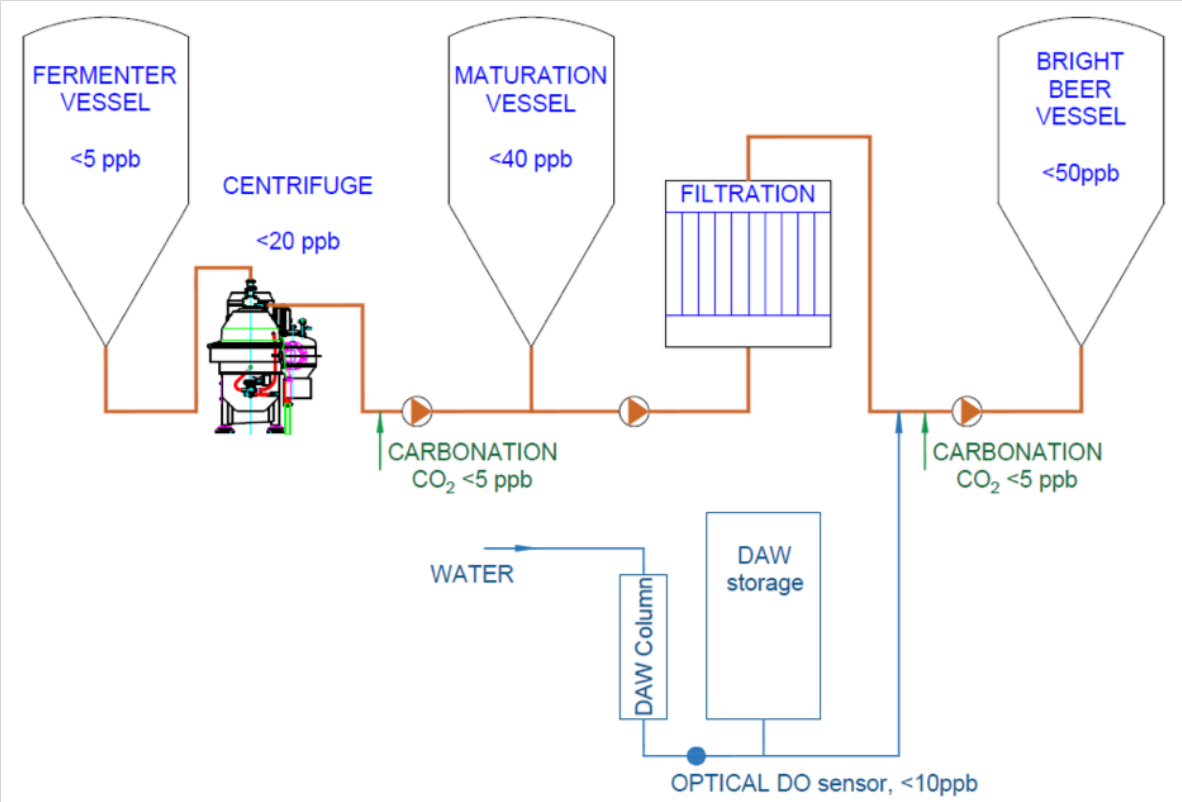
CHANGES IN BEER FLAVOUR WITH TIME

Dalgliesh has produced a famous diagram that shows the general sort of flavour changes that occur in beer over time:



In summary the following are best practice levels of Do throughout throughout the process:

- DO in CO2 supply should be <5ppb
- DO at end of fermentation <5ppb
- DO pick up across a centrifuge ideally <20ppb
- DO pick up across a filter ideally <20ppb
- DO in deaerated water supply <10ppb
- DO in Bright beer <50ppb
- DO pickup during packaging <50ppb
- TPO in pack <100ppb



2. METHODS TO REDUCE DO THROUGHOUT THE PROCESS

a. Brewhouse

Polyphenol concentration is affected by mashing, wort boiling, break formation and protein polyphenol precipitation. Polyphenols have an antioxidant capacity therefore reducing oxidation throughout the brewhouse particularly during low temperature mashing which has a positive impact on flavour stability.

a. Fermentation/Maturation/Bright Beer

SO2 forms complexes with aldehydes thus reducing their negative flavour impact so it is important to reduce oxygen ingress during fermentation to ensure that SO2 produced naturally during fermentation remains post fermentation and further processing.

a. Reducing Oxygen ingress by:

I. Tank purging and measuring the O2 to determine levels are low enough prefilling
II. Ensuring pumps are not leaking or cavitating or running dry during transfer.
III. Regular pump maintenance paying particular attention to mechanical seals
IV. Maintaining tank top pressure during transfer
V. Maintaining a back pressure during transfer
VI. Ensuring DAL has a low O2 if used to dilute pre-packaging
VII. Ensuring that CO2 blankets are maintained during centrifugation particular during yeast discharge
VIII. Maintaining a slight positive pressure during vessel opening for dry hopping
IX. Ensuring all process lines are purged with DAL or CO2 prior to any additions (stabilising agents etc)
X. Ensuring all tank seals are intact including sight glasses, manways, vacuum relief valve seals and any other fittings.

b. Reducing Oxygen ingress by:

XI. Ensure a positive pressure remains on the Fermenter pre chilling
XII. Ensuring beer temperature remains low during filtration/centrifugation or transfers
XIII. Ensuring Filtration equipment is purged or hot sterilized prefiltration.
XIV.O2 concentration in CO2 is checked prior to carbonation in-line or in vessel
XV. Measurement throughout the process is occurring and root cause analysis is conducted if issues occur
XVI. Cold temperature storage of beer occurs throughout the process post fermentation.

3. PACKAGING (KEGGING, BOTTLING, CANNING)

- CO2 purity is checked and keg purging rates post cleaning are optimized for low DO in headspace
- Counterpressure filling of kegs to reduce turbulence and thus O2 pick up
- All bottling or canning line processes are optimisied to reduce DO throughout the packaging process. To achieve optimal TPO figures in the realm of <100ppb
- Measurement and recording of O2 concentration throughout the process is of paramount importance. If high DO pick-up is noticed at any point this is call to stop production and investigate before proceeding.

If high DO issues are found throughout the process it is important to conduct root cause analysis and eliminate the cause. However once high DO is noticed if in vessel it is best to purge with high purity CO2 through a scinter stone at a slow rate to ensure to not flash off positive flavour volatiles or reduce head retention through over foaming. Ensure the beer is kept at as low a temperature as possible.

There are some additives that can be added however these are best added before issues occur but could be added to prevent further oxidation due to DO in the beer.

- Ascorbic acid
- SO2 (there are regulations around the addition of SO2 so be careful to heed these as it is considered an allergen)
- Rosmarinic acid (a natural polyphenol with antioxidant capacity and is generally added as part of the brewing process)

4. MEASUREMENT

To be able to control something it is necessary to be able to measure it. Common measurement equipment to determine concentration O2 in beer include:

Haffmans CO2/DO Meter:

- Robust unit, easy to use, quick and accurate measurement. Can be paired with a an in-package analyser for TPO measurement of cans and bottles.

CO_2/O_2 Gehaltemeter

General product information

In the beer and beverage industries, the content of dissolved carbon dioxide (CO_2) and oxygen (O_2) are determining factors in the quality, taste and flavor stability of beer and carbonated beverages. Particularly, O_2 is an important parameter as it causes a rapid decline of the flavor stability and shelf life. Because of this, breweries, as well as soft drink manufacturers continuously control and measure the concentrations of CO_2 and O_2 during production.

The CO_2/O_2 Gehaltemeter, type c-DGM, combines the internationally accepted determination of the dissolved CO_2 content based on Henry's Law with a highly accurate dissolved O_2 measurement. This state-of-the-art optical O_2 measurement technology is greatly improved compared to the traditional O_2 measuring instruments and doesn't require frequent calibration. The design allows for higher product pressure, making it suitable for the soft drink industry. Equipped with an advanced operator and location identification system, it allows for the traceability of measuring data and up to 10 different product types can be programmed into the instrument.

After operator/location identification, sampling takes place. When the CO_2 measurement is started, the O_2 content is stored. Automatically, equilibrium is created, followed by the measurement of pressure and temperature. The dissolved CO_2 content is then electronically calculated and displayed. The data can be securely transferred to a PC using the interface cable.

Besides the combined CO_2/O_2 measurement, the c-DGM is suitable for single O_2 measurement, continuous O_2 measurement and single CO_2 measurement.

Anton Paar Cbox:

- Quick and accurate measurement of CO2 and O2 needs a much smaller sample than the Haffmans unit and can be coupled with a proprietary in package analyser for TPO measurement of cans and bottles.

Combined CO_2 and O_2 Meter: CboxQC™

CboxQC™ is the precise combined CO_2 and O_2 meter which allows reliable QC on finished packages as well as highly accurate measurements in the laboratory for product development. It gives you fast, accurate, and reliable determination of dissolved carbon dioxide and oxygen in beverages. When combined with Anton Paar's PFD filling device, sample is taken directly from the package into the measuring chamber of CboxQC™ – with no loss of dissolved carbon dioxide and dissolved oxygen during sample transfer. CboxQC™ for the laboratory provides reliable CO_2 and O_2 results, even out of very small packages.

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Hach DO Meter:

- Measures O2 only is a cheaper alternative to the above 2 units
- Uses luminescent dissolved Oxygen technology which is different to the Optical measurement on the AP and Haffmans units

HACH

Lab Meters and Probes: Orbisphere Portables ▸ Orbisphere 3100 Portable Oxygen Analyser

Orbisphere 3100 Portable Oxygen Analyser

Overview | Downloads | Videos | Accessories

With Luminescent Dissolved Oxygen (LDO) technology integrated into the Orbisphere 3100, this analyser is guaranteed to improve process efficiency and provide accurate dissolved oxygen measurements.

Robust design that endures harsh environments
Designed for you at the plant floor in breweries and power plants

Fast response time and accurate measurements
Limited waste of sample and limited time spent taking measurements

Very low drift, requires less than once a year calibration/maintenance
Little downtime and low cost of ownership

User friendly instrument with colour display
Ideal for process spot check by plant operator

Help

Gallery

Hamilton Berverly:

- O2 measurement only. It is a robust unit with an optical DO sensor
- Cost effective portable DO measurement

Portable Dissolved Oxygen

Products | Applications | Resources

Beverly is designed for dissolved oxygen measurement in at-line and laboratory use in small and midsize breweries as well as in the beverage industry to provide excellent reliability in a rugged design, and purpose built to handle the environmental extremes encountered in everyday brewing operations.

Superior performance at an affordable price is achieved using Hamilton's best in class optical sensor VisiFerm DO with built-in intelligence, making Beverly the brewer's best friend.

Beverly Portable DO Meter Benefits

- Efficiency and serviceability of optical DO measurement
- Built to endure IP 67 watertight standards
- Robust, hygienic design
- Stamina for 50 hours of continuous operation
- Fast response time down to ppb level
- Calibration without removing the sensor

Sensory analysis (Fresh and aged):

The last line of defense, it is highly recommended that fresh and aged tasting be conducted on a regular basis within the brewery under blind tasting conditions. This regular tasting protocol has the benefit of training the internal panel members in aged characters which can then be used in unison with analysis to determine if a beer is commercially viable.

N.B: There is not widespread use of indigo carmine or caustic soda any more however these are basic and cheap options that could be pursued if capital expenditure is limited

5. BEST PRACTICE MEASUREMENT

- Dissolved Oxygen in pack should be tested as quickly as possible i.e. from filling to being analysed. If samples are left to stand too long the oxygen will start to react with the beer and you will get a lower than actual result.
- Allow time to flush your sensor with sample to eliminate any residual air in the instrument and temperature fluctuations. For example, if conducting an in-pack test take 2 samples; the first to flush your equipment and the second for actual measurement.
- If you pasteurise your beer where possible, measure your oxygen before pasteurisation. During pasteurisation up to 60% of the measurable oxygen is absorbed and therefore you do not get a realistic result.
- To obtain an approximate TPO result shake the package vigorously for at least 2 minutes prior to sampling. This assists the O2 within the package to equilibrate between the headspace and liquid.
- You can estimate your head-space oxygen by subtracting your DO from your TPO (you may achieve a negative value if your headspace is very low in O2). A high head-space oxygen result indicated that there may be opportunities to improve O2 evacuation of packaging pre-filling and CO2 blanketing (for cans) post filling/ pre-lidding.