# Oxygen

## the importance of measurement in soft drinks

Georg Janßen and Dr. Karin Biebernik assess the impact of oxygen in beverages.

At any stage during production or, more likely, during filling and capping, air might get into a soft drink package. Depending on the beverage's composition, significant levels of dissolved oxygen may have a considerable impact on a soft drink's quality and shelf life. To address all aspects of this topic requires considering not only the drink itself, but also the package type.

Many soft drinks contain ingredients such as fruit juices, pulp, or vitamins that are subject to oxidation. Elevated levels of dissolved oxygen ($O_2$) in these soft drinks may cause changes in the beverage's aroma and taste, changes in colour, and the loss of nutritional value. The more oxygen there is in the beverage container, be it dissolved in the beverage or gaseous in the head space, the faster the oxidation takes place. Oxidation is also enhanced by elevated temperatures. Over time, dissolved oxygen is consumed in these beverages by oxidation, and the depletion in the liquid is compensated by head space oxygen.

Soft drinks are available in numerous different packages. While non-carbonated soft drinks may also be sold in packages such as cartons or pouches, carbonated soft drinks are usually packaged in bottles and cans.

$O_2$ in a beverage container is always accompanied by nitrogen ($N_2$) as these are the main components of air, but only oxygen is the component that may interfere with beverage ingredients. Nitrogen remains in a package even if the oxygen content decreases over time due to oxidation reactions.

The solubility of both $O_2$ and $N_2$ in beverages is low. Thus, the majority of both gases is found in the head space. At higher temperatures the solubility decreases and more gas accumulates in the head space. This leads to a risk of an increased internal pressure, especially during pasteurisation, but also during the product's entire shelf life.

Figure 7: Recommended stages of $O_2$ measurement in the soft drink production process.

Figure 5: OxyQC, CarboQC, and CboxQC.

### The package material can make a difference

The most frequently used polymer for soft drink bottles is polyethylene terephthalate (PET) [1]. As PET has a certain degree of gas permeability [2], PET bottles allow the ingress of oxygen through the package walls and closure over time [3] (Figure 1). To a much smaller extent, oxygen can also get into glass bottles at the closure/glass interface. The oxygen ingress was found to be 2.1 mg to 2.5 mg per year [4]. Sealed beverage cans hardly allow any oxygen ingress at all. Nevertheless, also here oxygen has to be monitored as it may enter the can during the production and filling process and harm the beverage as well as the can.

### The impact of $O_2$ on soft drinks in PET bottles

Only samples with similar head space to liquid ratios are eligible for investigation to avoid erroneous conclusions. Measurement results obtained on beverages without oxidisable components in PET bottles over a period of several weeks showed an increase of dissolved oxygen (Figure 1). The PET bottles under consideration came from the same batch and were shaken to establish equilibrium between head space and liquid.

### The impact of oxygen on soft drinks in cans

Oxygen can cause changes to beverages in cans, depending on the beverage composition as the four examples in Figure 2 show. Only water showed no changes in the dissolved $O_2$ concentration as there are no components present that oxidise.

A metallic taste in a beverage may be due to the presence of oxygen in the can. High oxygen levels contribute to an enhanced risk of can corrosion processes such as an increased risk regarding perforation and metal uptake (Figure 3).

Air content and metal pickup were shown to correlate by comparing two groups of aluminium cans, filled with test solutions with an increased or standard air level. Also the variance, as indicated by the orange-coloured bar, was much wider with Group 1 (increased air level).

### The impact of oxygen on cans

When in direct contact with amphoteric aluminium metal, a clear relation between air – or oxygen dissolved in the beverage – and can corrosion can be observed. The extent of the impact of oxygen on metal cans was visualised: cans with intentionally scratched internal coating were filled with samples of (i) low air contents (2 mL) and filled with undercover gassing (blue dots) and (ii) high air contents (18 mL) filled without undercover gassing (red dots) (Figure 4).

Held at a constant temperature of 37 °C, cans with high air contents displayed visible failures or leakages after 7 days already. After an observation period of 33 days, all cans without undercover gasser showed failures, while the cans filled with undercover gasser showed no failures at all.

### Anton Paar's measurement solutions for soft drinks

Anton Paar's portfolio comprises a variety of different instrument versions to fulfil the respective needs and requirements, be it in the lab or in production.

For measurements in the laboratory, the OxyQC $O_2$ meter for beverages (0 ppm to 4 ppm $O_2$) or the OxyQC Wide Range $O_2$ meter for beverages (0.015 ppm to 45 ppm $O_2$), shown in Figure 5, represent a well-proven option for the determination of dissolved oxygen in the lab as well as at-line while CboxQC allows the simultaneous determination of $CO_2$ and $O_2$. CboxQC is also available as an at-line version.

To round up Anton Paar's portfolio of laboratory oxygen meters for soft drinks, the oxygen measuring module Option O2 is designed to be used in combination with the Packaged Beverage Analyzers for Soft Drinks (PBA-S/SI/SID).

For continuous monitoring of the oxygen content during production, the Oxy 510 inline oxygen sensor (Figure 6) represents a reliable solution.

Oxygen needs to be avoided all the way through soft drink production. Thus, it is equally important to measure oxygen inline or in the bypass as well as in the lab in the already packaged product.

The oxygen result obtained with process instrumentation during production and with laboratory instruments obtained on packaged products may not be the same. There are several explanations for that fact. Due to the low solubility of oxygen in beverages, the dissolved oxygen content is expected to be lower in packaged samples, the remaining oxygen will be found in the head space. The warmer the sample, the more oxygen will migrate into the head space. Also, oxygen may get into the package during the filling and closing of the package.

Several methods to align process and laboratory instruments offer themselves and are found to be applied by soft drink manufacturers:

(1) When measuring inline, the result of the inline oxygen meter is compared to the total package oxygen content of the final and already packaged product. If required, the inline oxygen meter has to be adjusted with a reference gas.

(2) Another way of aligning lab and process instrumentation is the adjustment of the inline instrument with a laboratory oxygen meter (e.g. OxyQC or CboxQC/At-line). In this case, it is required to create different methods for different

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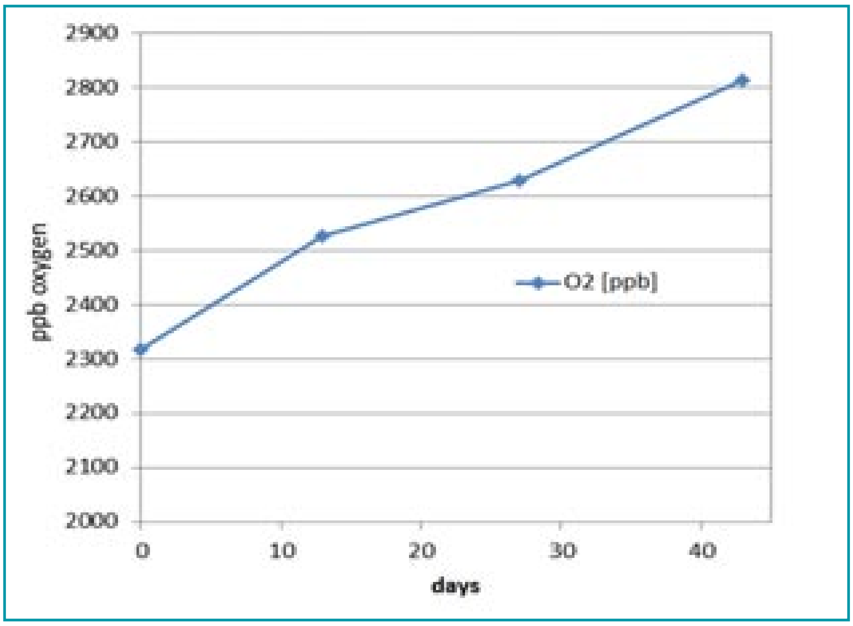


*Figure 1: Change of dissolved O2 in PET bottles over time.*

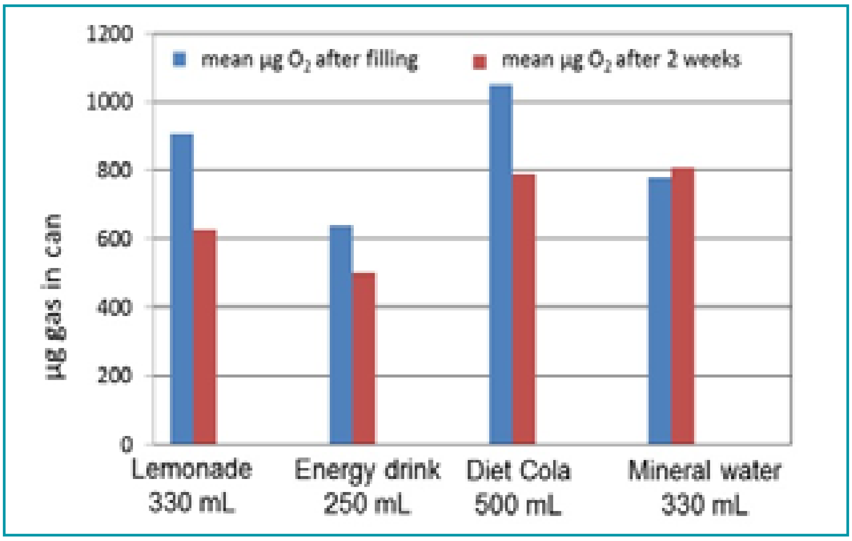


*Figure 2: Observed changes of $O_2$ in unblemished cans, shown in micrograms immediately after filling and two weeks after filling showed a decrease of $O_2$.*

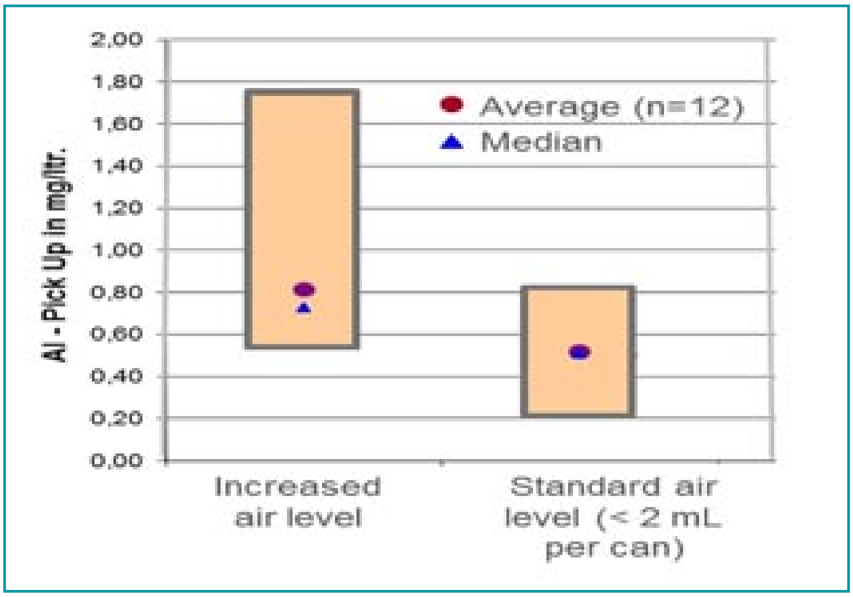


*Figure 3: Air content and metal pickup after 14 days at 37 °C.*

*Figure 6: Oxy 510 inline oxygen sensor $O_2$ measurement in the lab and during production.*

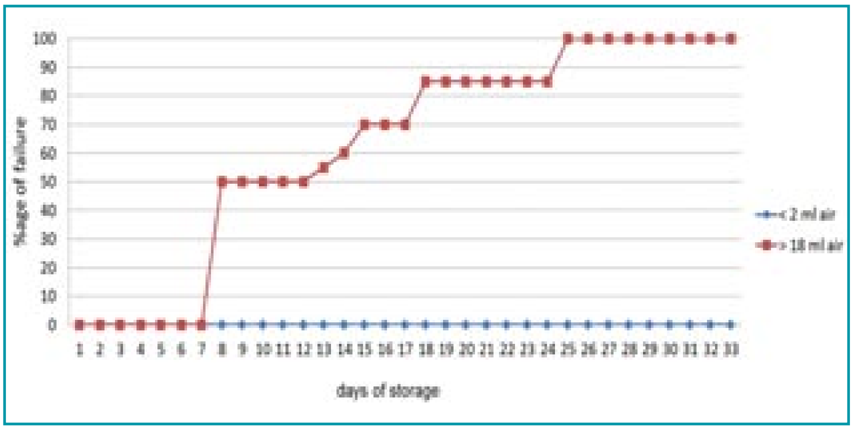


*Figure 4: Failure rate in correlation to dissolved air content.*

**OXYGEN**
**– continued from page 75**

package sizes and/or types because their head space to liquid ratio may differ, for example a method for 0.5 L PET bottles and another method for 0.33 L cans.

(3) A third way is to connect a CboxQC At-line or OxyQC to the line and compare the readings to the readings on the inline oxygen meter.

What remains is the question: what does the reading on the inline meter have to be in order to avoid going over the maximum allowed level in the already packaged product? The possible sources have to be identified and avoided!

### Possible sources of oxygen ingress

The main sources of oxygen ingress in the course of a soft drink production process are found in

- raw material delivery,
- process water,
- tanks,
- pre-filler, premix,
- filler, and
- seaming / capping.

Figure 7 marks the stages of soft drink production with a red circle where the measurement of oxygen should be carried out to help ensure the quality and shelf life of the final product.

### How to avoid oxygen ingress

Based on the possible sources of ingress, considerations of how to eliminate high oxygen levels in soft drinks suggest themselves.

The recommendations to avoid oxygen include

- ensuring a smart design of the filling line – piping system, tanks, agitators, pumps, …
- de-aerating process water,
- purging the storage tanks,
- de-aerating at premix,
- accurately adjusting the filler, and
- sufficiently adjusting the undercover gassing in the seamer to ensure inertisation of the container's head space.

A good product starts with the very first production step!

To ensure optimum end products, oxygen ingress has to be minimised from the beginning all through the production process. This makes monitoring the soft drink production from the very beginning at every single production step equally important. ■

Oxygen needs to be avoided all the way through soft drink production.

***References:***

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