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MASTER BREWERS ASSOCIATION OF THE AMERICAS

Aspects of optical and traditional measurement of dissolved carbon dioxide by in-line, at-line and laboratory instrumentation

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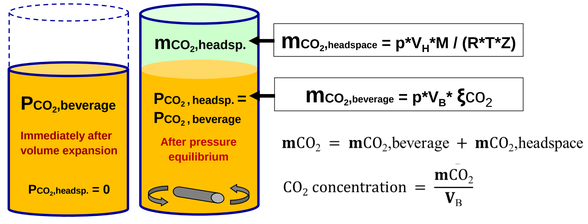
Introduction:

Optical measurement technology in general is becoming more common in process environments, especially in the brewing and beverage industry, and offers many benefits, such as ease of installation, cleaning and compact size. Optical sensors also have no moving parts and are considered maintenance free.

Most methods used for CO_2 measurement in the laboratory are based on Henry's and Dalton's laws. This poster deals with the aspects of optical versus traditional measurement of dissolved carbon dioxide and how/whether both of those measurement principles can be employed together for quality checks in the beverage production process.

Measuring principle of CO_2 based on pressure/temperature:

Most *at-line and laboratory instruments* are using the classical method of CO_2 analysis according to Henry's law. At-line instruments are using a measuring chamber. After filling of the measuring chamber with the sample, the measuring chamber will be closed and its volume expanded by a piston or diaphragm. Best method to reach pressure equilibrium in the measuring chamber is an impeller. Once equilibrium is established, pressure and temperature are measured and the CO_2 content is calculated:



$$m_{CO_2,headspace} = p * V_H * M / (R * T * Z)$$

$$m_{CO_2,beverage} = p * V_B * \xi CO_2$$

$$mCO_2 = mCO_2,beverage + mCO_2,headspace$$

$$CO_2 \text{ concentration} = \frac{mCO_2}{V_B}$$

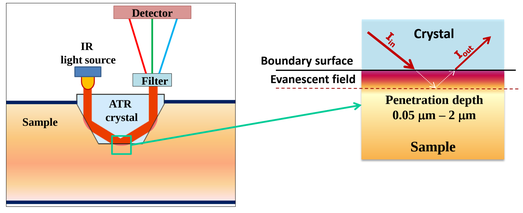
p ... CO_2 partial pressure	V_B ... volume beverage	R ... gas constant
m ... mass of CO_2	V_H … volume head space	T ... temperature
ξ ... solubility	M ... molar mass	Z ... coefficient of compressibility

The solubility strongly depends on the temperature and beverage composition. The CO_2 solubility in beverages is up to 20% lower than it is in pure water. The solubility coefficients of each beverage type are predefined in the CO_2 meter.

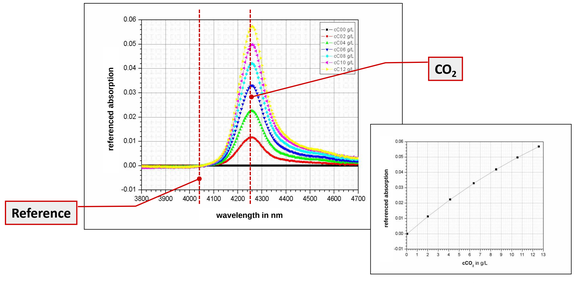
Modern *at-line and laboratory instruments* combine the classical method of CO_2 analysis according to Henry's law with the "Multiple Volume Expansion Method" (MVE) which makes use of the fact that the solubility of CO_2 in beverages is much higher than the solubility of other gases.

Measuring principle of CO_2 based on NIR absorption:

The measurement principle is based on the Attenuated Total Reflection (ATR) method. A beam of infrared light is passed through the crystal. The beam is reflected at the internal surface in contact with the sample. The intensity of specific absorption bands of the reflected beam is measured by a detector and the corresponding CO_2 value is calculated:



The infrared light absorption takes place in the surface layer (evanescent wave). As water also absorbs light, a reference measurement is necessary to determine the CO_2 content:



Additionally, the absorption depends on the penetration depth of the light beam, which is influenced by the beverage composition. Therefore, Carbo 520 uses an additional reference beam to compensate this influence. For example, a change of 1°Plato can generate an error of 0.1 Vol CO_2. The reference beam allows a special factory adjustment for accurate measurement results of all beverage types without any influence from the beverage composition.

Deviations between the methods:

In-line, at-line and laboratory instrumentation may show small deviations in their results. What are the reasons for the deviations and how large can the deviations be and what can be done to minimize them?

Measuring accuracy of the pressure/temperature method:

The measuring accuracy depends on the used instrument. Highest accuracy is achieved with instruments using the MVE Method. As the solubility is influenced by the beverage composition (types), beverage methods can be selected on the instrument. Methods are for example beer, strong beer, soft drinks,… The following table shows the influence from solubility on the amount of dissolved carbon dioxide, at the same carbonation pressure:

Beverage type	CO_2 [g/l]	CO_2 [Vol]
Water	5,89	2,98
Mineral water	5,85	2,96
Diet beverage	5,73	2,90
Soft Drink	5,17	2,61
Beer	5,46	2,76
Strong beer	5,25	2,66
Sparkling wine	5,14	2,60
MID (low sugar)	5,45	2,76

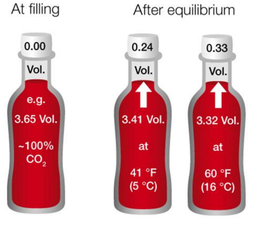
For beverages that do not match any of these pre-defined types, the CO_2 solubility coefficient can be determined and stored on the instrument.

Measuring accuracy of the NIR absorption method:

For the factory adjustment of the new Carbo 520, the CarboQC using the "Multiple Volume Expansion Method" is used. For highest accuracy, special adjustment liquids with accurately known solubility are used.

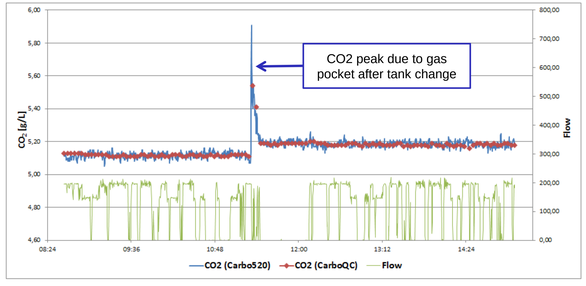
In-line, at-line versus bottle/can measurement:

During the filling process, the CO_2 content in the beverage may change. Additionally the head space volume in the package and the beverage temperature influence the remaining CO_2 content in the beverage. For example, at higher beverage temperatures more CO_2 will move from the beverage to the head space:

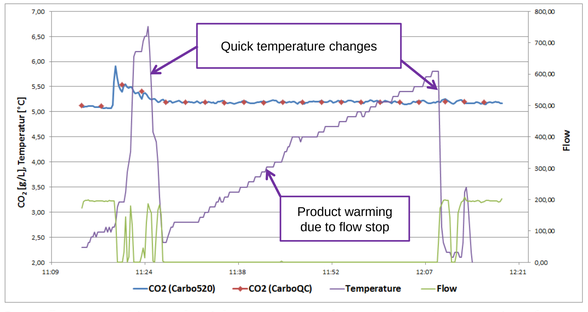


Results of a head to head comparison:

A head to head comparison test was made in a German brewery. In-line data (Carbo 520) were recorded every 15 seconds. At-line measurements (CarboQC) were made every 3 minutes:



Between tank changes high variations in CO_2 are seen due to residual CO_2 gas in the pipe. Very short high peaks in CO_2 can only be seen by in-line measurement.



Long flow stops, high and quick temperature changes do not have any interference on the in-line measurement with the Carbo 520.

Summary:

The new optical in-line measurement Carbo 520 shows excellent correlation to the at-line measurement with CarboQC. It is a drift free measurement and tracks quick concentration changes within a high degree of accuracy.

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