

Influence of Dissolved CO₂ on the Measurement of Diet Beverages

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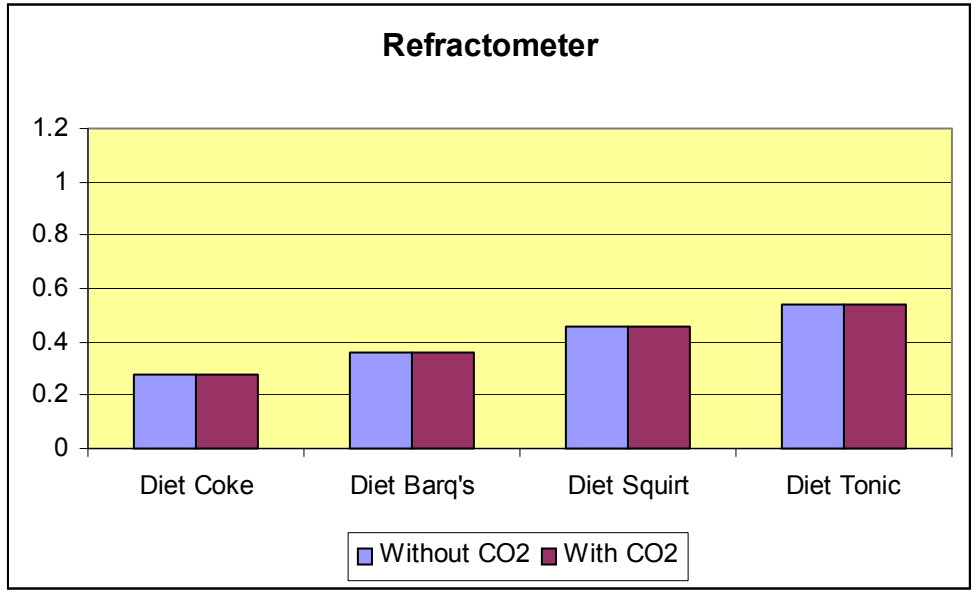
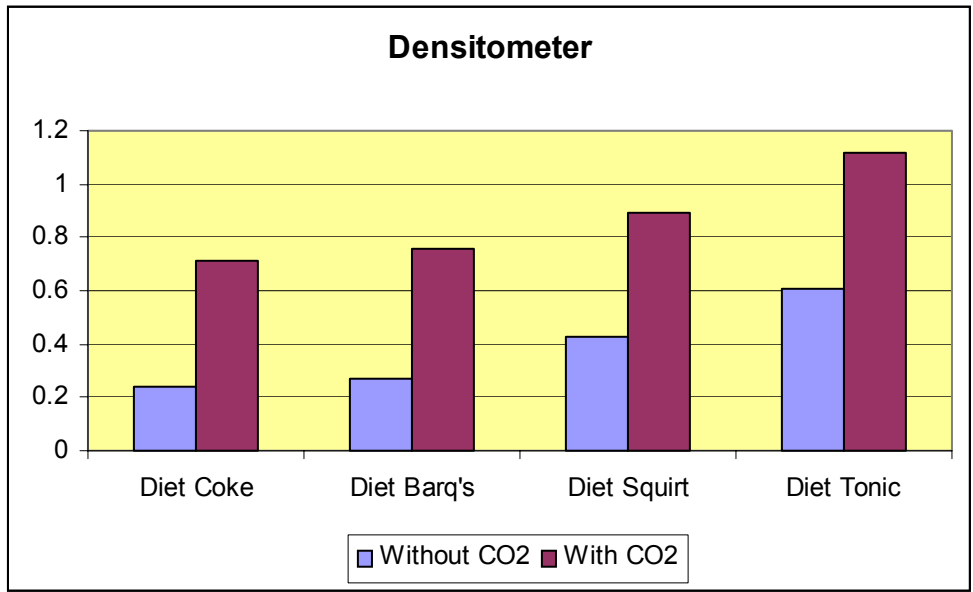
The presence of dissolved CO₂ in soft drink beverages can influence the measurement of the concentration, especially for Diet flavors. The magnitude of this effect, however, is dramatically different for the different technologies presently used to measure carbonated beverages on-line. This article will explain why the presence of carbonation has virtually no affect on the Diet measurement by Refractive Index, which is the technology used in the Maselli Beverage Analysis System, and why even very small changes in dissolved carbonation will disturb any on-line Densitometer to a magnitude that prevents it from reaching the accuracy and repeatability needed for Diet Cola flavors.

The quantity of CO₂ dissolved in beverages is usually defined either in terms of “Volumes” or “g/l”. The first method defines the number of volumes of the gas under standard conditions (0°C and 1 Atm) that are dissolved in each volume of the liquid. The second method indicates the grams of CO₂ that are dissolved in each liter of liquid. One Volume of carbonation is approximately equal to 2 g/l. Typical carbonated soft drinks contain about 4 Volumes = 8 g/l of dissolved CO₂.

A Refractometer measures the concentration of a liquid using an optical principle called the Refractive Index. A Refractometer will detect the addition of 8 g/l of CO₂ (4 Vol.) the same as if 8 grams of water were added to each liter of beverage. Consequently, the effect on the Refractive Index is the same as if the solids of the beverage were distributed over a slightly larger volume of water. In fact, the addition of 8 g/l of CO₂ will change the Refractive Index reading of a Diet beverage by only 0.003 Brix. Since Diet Cola flavors contain very few solids and read approximately 0.2 Brix compared with treated water, 0.003 Brix represents about 1.5% of the Diet Cola reading.

On the other hand, a Densitometer measures the total weight of the liquid inside a chamber. Adding the same 8 g/l of CO₂ is approximately the same as increasing the weight of one liter of liquid by an additional 8 grams, thus increasing the density. Taking into consideration the effect of the CO₂ gas on the volume of liquid, the net change in density due to a change of 8 g/l is approximately 0.54 Brix, which is approximately 270% of the Diet Cola reading!

This is why in laboratory measurements it is unnecessary to de-gas the sample before measuring the beverage with a Refractometer, except to insure that free bubbles do not collect on the surface of the measuring prism. A laboratory bench Densitometer, however, must be completely de-gassed before it can possibly read the beverage accurately.



Of course, carbonation changes in a normal beverage production line prior to bottling should never approach the 4 Volumes or 8 g/l magnitude, which would be the difference between uncarbonated and fully carbonated conditions. Fluctuations during normal production can be 0.1 Volumes (0.2 g/l) or more, even on stable lines. If we consider the phenomena described above in terms of a small change of 0.05 Vol (0.1 g/l), we see that the effect on a Diet measurement using a Refractometer is less than 0.02% of the standard measurement, which is 25 times less than the “0.5% of Standard” accuracy desired by the major Cola franchise companies. In fact, the in-line measurement by Refractive Index is essentially not affected at all by changes in dissolved carbonation, and therefore no compensation for CO2 changes is needed.

Calculating the effect of the same 0.05 Vol fluctuation on an in-line Densitometer, however, we can immediately see that even this small change in CO₂ will distort the density-based Diet Cola reading by approximately 3.5% of Standard... which is still 7 times the “0.5% of Standard” accuracy needed for the reading! This phenomenon is not specifically related to any particular brand of Densitometer, but rather to the physical principle used by all Densitometers.

Error in Diet Cola Measurement per 0.05 Vol. (0.1 g/l) CO₂	
Densitometer:	3.5% of Standard
Refractometer:	<0.02% of Standard

Both types of analyzers are capable of detecting very small changes in concentration, sufficient to meet or exceed the “0.5% of Standard” precision under controlled conditions which exclude the influence of changes in dissolved CO₂. In theory, a solution to this problem for Densitometers might be to compensate the Diet Brix reading for even very small changes in the dissolved carbonation, in order to eliminate its influence on the final reading. However, considering that 0.05 Vol (1 g/l) will create a 3.5% error, the compensation would have to be completely accurate to better than $0.05/7 = 0.007$ Volumes (0.014 g/l) just to reduce the error caused by the CO₂ to something less than the total allowed measurement error. And this would still leave no margin for the normal errors in the Densitometer’s reading itself. Since the sensitivity and repeatability of the in-line carbonation analyzers do not provide this precision, it is physically impossible to measure Diet Cola flavors with the accuracy and repeatability expected by modern bottlers when using Densitometer-based analyzers.