European Brewery Convention

EBC PRESS REPORT

CO_2 Correction Factor for the Net Contents of Containers

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SUMMARY

A new formula to replace the current EBC formula for the correction of net contents in beer containers for the presence of CO_2 has been derived from a bibliographic study that reviews the influence of carbonation on beer density determinations. The study reviews the relationship between beer density and CO_2 partial molal volume (PMV) as defined by the American Society of Brewing Chemists (ASBC) (ASBC Methods of Analysis Fills–1 formula) and that given by the European Brewery Convention Analysis Committee (EBC) and shows that in the current EBC equation a CO_2 PMV of 0.65 mL/g and a residual CO_2 content after degassing of 0 v/v or % (m/m) is used. Experimental determination of CO_2 PMV gives values of 0.73 ± 0.01 mL/g for most of the standard European beers as Lager, Pilsener, Premium and Export styles. Residual CO_2 levels after decarbonation were quantified for a series of degassing methods and were found to be between 0.20 to 0.50 v/v average 0.40 v/v or 0.08% (m/m). A new equation for determining the CO_2 correction was then proposed assuming a PMV of 0.73 mL/g and a beer carbonation level of 0.40 v/v or 0.08% (m/m) after normal degassing. The new formula is recommended for inclusion in Analytica-EBC replacing the current formula.

INTRODUCTION

Packaged beer must comply with regulatory requirements with respect to the volume of the contents. Some measurement methods for determining the volume of beer in a container use a weight determination. The calculation for conversion from weight to volume uses beer density or specific gravity. The European Brewing Convention procedure (EBC Method 11.3.1 Net Content of Bottles and Cans: Weighing Method) (1) provides two alternative calculations for this conversion, one being a more accurate calculation that accounts for the carbon dioxide present in the beer in the package. The presence of CO_2 in the beer has the effect of increasing the beer volume. The change in density of beer with carbonation is expressed by the partial molal volume (PMV) of CO_2. The PMV of CO_2 is not a universal constant, but varies for different liquids or solvents in which CO_2 is dissolved. For example water volume increases by 0.85 mL for every gram of CO_2 added. Also, during the determination of density or specific gravity, the presence of CO_2, resulting from incomplete degassing, reduces the density or specific gravity value obtained. The more accurate EBC method for the determination of volume contents should therefore correct the volume for the contribution of CO_2 in the beer and the contribution of CO_2 on the density.

Studies (2) (3) – including the modelling of beer density as a function of its composition in terms of sugar, ethanol and CO_2 content – determined experimentally the CO_2 PMV in nine beer products.

MODELLING

An equation (2) adopted by the ASBC (4) calculates the density of carbonated beer as a function of the CO_2 content in the original beer as well as the carbonation level of the "decarbonated" beer at which the density was measured:

$$dc = \frac{(1 - P \times d) \times \left(V - W - \frac{V \times W)}{k \times d} \right)}{k - (P \times W)} + 0{,}997 \times s + 0{,}0012 \qquad \text{Equation I}$$

where

dc = corrected density 20°C/4°C of the beer (g/mL)
P = CO_2 partial molal volume (PMV) (mL/g)
V = CO_2 by volume in the beer
W = residual CO_2 by volume in the decarbonated beer
k = conversion constant for CO_2 in volumes to CO_2 by weight
= 506.07 mL/g
d = uncorrected density of beer at 20°C g/mL
= 0.997 × s + 0.0012
s = specific gravity 20°C/20°C of the beer.

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TABLE I. Extracts, Ethanol and PMV Concentrations of Test Beers

Measured Characteristic		Water	NAB	LAB	Light	Regular	Lager	Pilsen	Malt Liquor ~ Marzen	Bock	Dry Bock
Apparent Extract	% P	0	3.85	6.2	0.1	1.6	2.0	1.9	2.55	2.75	0.1
Real Extract	% P	0	3.86	6.40	1.48	3.18	3.77	3.72	4.73	5.22	2.90
Alcohol	% (m/m)	0	0.01	0.48	3.26	3.51	3.95	4.08	4.85	5.57	6.74
	% (V/V)	0	0.01	0.62	4.12	4.46	5.04	5.20	6.07	7.11	8.52
Original Extract	% P	0	3.90	7.40	7.95	10.10	11.45	11.65	14.03	15.78	15.70
PMV	mL/g	0.875	0.85	0.78	0.81	0.79	0.73	0.74	0.69	0.65	0.68

It can be seen from the above equation that precise PMV values for CO_2 in beer and the CO_2 concentration for the decarbonated beer are needed to calculate beer density accurately as a function of carbonation level.

The correction equation to compensate for carbonation in Analytica-EBC, in terms of % (m/m) of CO_2 (a) is given currently as (1):

$$dc = (a \times 3.6 \times 0.001 + s) \times 0.997 + 0.0012$$

or in terms of volumetric units (v/v):

$$dc = \left(\frac{V}{5.0607 \times SG} \times 3.6 \times 0.001 + s \right) \times 0.997 + 0.0012$$

Equation I implies, by comparison with the EBC equation, an equivalent PMV of approximately 0.65 mL/g and a residual CO_2 in the decarbonated beer (W) equal to 0 v/v or % (m/m).

EXPERIMENTAL

Table I summarizes the average CO_2 PMV results for the products tested (beers from United States and Europe) (3). The CO_2 PMV for these products ranged between 0.65 and 0.85 mL/g.

The results for CO_2 PMV were significantly different. The difference might be due to the binding of CO_2 to protein and dextrins, although the understanding and documentation of this binding is far from complete.

An empirical robust equation was determined that models the CO_2 PMV as a function of beer composition where EOH is the ethanol concentration (% (m/m)) and RE the real extract (% P):

$$PMV = 0.9045 - 0.02988\,(EOH) - 0.002939\,(RE)^2$$

For standard European beers (as Lagers, Pilsener, Premium, Export styles…) in the following ranges:

Apparent Extract	(% P)	2.2–3.0
Real Extract	(% P)	3.5–5.0
Alcohol	(% (m/m))	3.5–4.5
	(% (V/V))	4.5–5.5
Original Extract	(% P)	11.0–13.0

the estimated PMV value would be 0.73 ± 0.01 mL/g.

Degassing techniques (3) (5) (6) (7) (pouring, filtration, sonication and/or shaking) vary in their effectiveness in removal of CO_2 (and retention of ethanol) but typically achieve values between 0.20 to 0.50 v/v average 0.40 v/v or 0.08% (m/m) of residual CO_2.

By looking at the relative order of magnitude of the various terms in equation I, a simplified version can be derived:

$$dc = \frac{(1 - P \times d)(V - W)}{k - (P \times W)} + 0.997 \times s + 0.0012$$

Equation II

or in terms of % (m/m) of carbonation:

$$dc = \frac{(1 - P \times d)(a - a_0)}{\frac{100}{d} - (P \times a_0)} + 0{,}997 \times s + 0{,}0012$$

where

$a =$ CO_2 % (m/m) in the beer

$a_0 =$ residual CO_2 % (m/m) in the decarbonated beer.

The difference between equations I (ASBC) and II (full and simplified) was numerically verified to be less than 2×10^{-6} g/mL for up to 3 v/v of carbonation.

Assuming an equivalent PMV for the standard European beers of 0.73 mL/g and a residual CO_2 of 0.40 v/v or 0.08% (m/m), the corresponding EBC correction equation to compensate for carbonation in the EBC methods, in terms of % (m/m) of CO_2, would be:

$$dc = (a \times 2.5 \times 0.001 + s) \times 0.997 + 0.0012$$

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