THE BUZZ

Brewing Calculations

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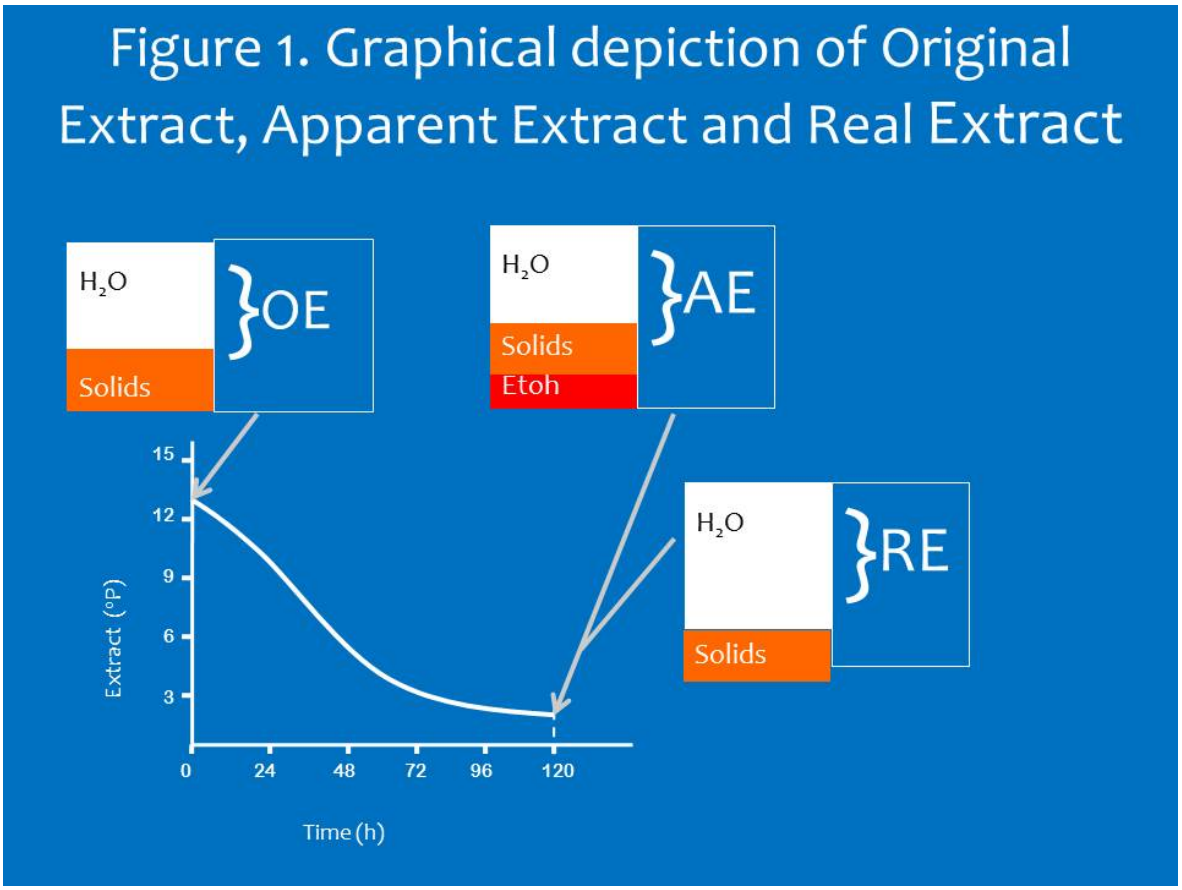
Most brewers in Europe and the new world are familiar with the acronyms OE, AE, and RE. The Original Extract (OE) in °Plato is the percent solids (w/w) in unfermented wort as expressed as % sucrose. The Apparent Extract (AE) refers to the density of an equivalent sucrose solution (i.e., 10°P=10% w/w sucrose), assuming no alcohol is present. Finally, the Real Extract (RE) represents the actual or "real" solids content of a beer. Thus the AE value of a beer will always be lower than the RE if alcohol is present. Figure 1 illustrates these values.

The measurement of OE, AE, RE, as well as % alcohol ($A_{w/w}$) can be undertaken in various ways. In the past these measurements were primarily carried out by use of tedious distillations and density measurements. Various modern methods exist to quantify these four beer parameters; the most common involves use of the Anton-Paar Alcolyzer, which combines density and NIR measurements (as noted in Beer-4G in the *ASBC Methods of Analysis*).



Knowing OE, AE, and RE, the extent of a fermentation (i.e., its attenuation), measured as the Apparent Degree and Real Degree of fermentation (i.e., ADF or RDF) can be easily calculated:

$$ADF = 100 \cdot \frac{OE - AE}{OE}$$

or

$$RDF = \left(100 \cdot \frac{OE - RE}{OE}\right)\left(\frac{1}{1 - 0.005161 \cdot RE}\right)$$

These formulas are mentioned in Beer-6 in the *ASBC Methods of Analysis.* The constant 0.005161 corrects for the mass lost by CO_2 evolution and yeast uptake when wort is fermented.

One other well-known formula is Balling's Equation:

$$OE = \frac{100 \cdot \left(2.0665 \cdot A_{w/w} + RE\right)}{100 + 1.0665 \cdot A_{w/w}}$$

Balling's formula can be used to calculate the OE of a beer knowing the alcohol and RE values. The constants in Balling's formula are based on approximations of the amount of yeast produced during fermentation. The formula is an approximation (Cutaia et al. 2009) and subject to error when back-calculating OE from a high-gravity diluted beer. Nonetheless development of the formula was an amazing achievement for the 1860s!

These calculations are normally as far as most brewing texts and breweries go when monitoring their process. In large breweries, the determination of OE, AE, RE, and $A_{w/w}$ is reasonably straightforward and allows the brewer to monitor and government excise/tax departments to tax the process.

But knowledge of RE and $A_{w/w}$ values is difficult for home, brewpub, and craft brewers to obtain. Often these brewers only know the original and apparent extract values of their beer. They are left wondering about the corresponding RE and $A_{w/w}$ values. While the Internet has a bewildering number of calculators to estimate RE and $A_{w/w}$, they leave the viewer with little confidence in the resultant values.

However if one is willing to use basic but extensive algebra, the values for $A_{w/w}$ and RE can be calculated. An expression first derived by Pawloski and Doemens (1932) and modified slightly by Cutaia et al. (2009) gives a reasonable and statistical reliable approximation of alcohol content:

$$A_{w/w} = (3.72 \times 10^{-1} + 3.57 \times 10^{-3} * OE) * (OE - AE)$$

A more intricate expression existing for calculation of RE from AE and alcohol levels has also been reported (Cutaia et al. 2009):

$$RE = 0.496815689 * Aw/w + 1.001534136 * AE - 0.000591051 * Aw/w * AE - 0.000294307 * AE^2 - 0.0084747 * Aw/w^2 + 0.000183564 * Aw/w^3 + 0.000011151 * AE^3 + 0.000002452 * Aw/w^2 * AE^2$$

The expression was based on an examination of five fermentation datasets from 512 fermentations. While complex, these equations can be easily inserted into an Excel spreadsheet, thus facilitating easy calculation (and minimizing eyestrain!). Hopefully these expressions will eventually be incorporated into the *ASBC Method of Analysis*.

Finally, the reader should be aware that various calculators for conversion of Specific Gravity to °Plato or $A_{w/w}$ to $A_{v/v}$ and various factors exist on the *ASBC Methods of Analysis* website.

These calculations can be very useful in the craft industry as many breweries have equipment for measuring the density, but not alcohol or RE values.

References:

Cutaia, A. J.; Reid, A.-J.; and Speers; R. A. Examination of the Relationships between Original, Real and Apparent Extracts, and Alcohol in Pilot Plant and Commercially Produced Beers. *J. Inst. Brew*. 2009, 115:318–327.

Pawloski, R.; and Doemens, A. *Die Brautechnischen Untersuchungs-Methoden*. Verlag von R: Oldenburg, Munch, 1932.