Predicting alcohol levels

Over the past two vintages winemakers have been reporting higher than normal conversions of sugar to alcohol. One example was a must measured at 13.5 Baume that ended up with a 15% v/v alcohol concentration. Estimating potential alcohols based on grape must analysis is not as straightforward as many winemakers assume. This article addresses some key points to be taken into account.

THE SCIENCE

Theoretically, yeast converts sugar into almost equal masses of ethanol and carbon dioxide (CO_2) gas, by the Gay-Lussac equation:

Glucose	Ethanol	Carbon dioxide
$C_6H_{12}O_6 \rightarrow$	$2CH_3CH_2OH$ +	$2CO_2$
180 g	92 g (51%) +	88 g (49%)

In reality, however, some sugar is converted to energy and yeast cell growth (biomass production) and some ethanol vapour is lost to the environment. Ethanol yields are only ever around 90% of the theoretical value.

INITIAL SUGAR CONCENTRATION

Baume or Brix measures are commonly used as quick estimates of sugar content in grape samples or must. It has become a 'rule of thumb' to expect that 1 Baume = 1.8 Brix = 18 g/L sugar = 1% potential alcohol.

It is important to remember that Baume and Brix do not actually measure a sugar concentration or sugar weight per unit volume. Instead they measure the specific gravity of a solution, or a volume measurement only. A hydrometer displaces a volume of liquid, with the equivalent volumes calibrated at known sucrose concentrations. These measures work as estimates because ripe fruit is 90-95% sugar, with the remaining solids including pigments, tannins, organic acids, pectins, salts and non-fermentable sugars.

To better estimate potential alcohols Brix measurements can be converted into sugar concentrations, by also measuring the specific gravity (SG) of the juice, and using the equation:

Sugar concentration (g/L) = Brix x SG x 10 x 0.9982

Since SG varies with sugar concentration, it is not possible to generate a simple potential alcohol table using Brix or Baume values without also measuring the SG.

CALCULATING POTENTIAL ALCOHOL

Only fermentable sugars are converted to ethanol, so it is more accurate to measure the glucose and fructose concentration rather than Baume or Brix, to calculate potential alcohol.

Potential alcohol (% v/v) = glucose+fructose (g/L) / 16.83

Many people think the conversion factor is 18 g/L, but the official European conversion ratio is 16.83g fermentable sugar per litre for 1% v/v alcohol. Note that the conversion rate is highly yeast dependent and can vary from 16.5-17.2 g/L sugar for 1% alcohol, with some reporting up to 17.98 (or rounded to 18). Yeast studies at the AWRI have shown an average factor around 16.4 g/L

Using the extremes of the possible conversion rates described above, for 250 g/L sugar (~13.9Be), the alcohol concentration generated could be anywhere between 13.9% and 15.2% v/v. Table 1 (adapted with permission from ETS Laboratories) gives a summary of potential alcohol concentrations for a range of initial sugar concentrations.

Table 1. Range of potential alcohol concentrations that can be generated from different initial sugar concentrations

Fermentable sugar (g/L)	Potential ethanol (% v/v)
180	10.0-10.9
190	10.6-11.5
200	11.1-12.1
210	11.7-12.7
220	12.2-13.3
230	12.8-13.9
240	13.3-14.5
250	13.9-15.2
260	14.4-15.8

It is also possible to calculate the sugar to alcohol conversion rate at a particular winery for the specific yeast, grapes and ferment conditions commonly used, to be able to better predict potential alcohols for future ferments.

FERMENTATION EFFECTS

Lallemand Australia fermentation trials have shown that alcohol conversion rate is affected by fermentation conditions, specifically:

- Lower temperature ferments result in higher alcohol levels (due to less alcohol evaporation);
- Lower surface area to volume ratio tanks result in higher alcohol (again due to less evaporation);
- Aeration of ferments results in lower alcohol (due to increased evaporation); and
- Nutrient levels can affect the rate in different ways dependent on yeast strain.

MOST COMMON REASON FOR UNEXPECTED ALCOHOL CONCENTRATION

When a much higher alcohol concentration than expected is encountered, it is often put down to super-efficient yeast. Based on AWRI helpdesk investigations, however, the more likely reason is an inaccurate initial sugar reading.

This particularly occurs in hot years, when grapes are more shrivelled and there are higher solids/skins to liquid ratios.

When pressing shrivelled grapes it is difficult to extract a representative liquid sample to measure and the sugars stored in the grape skins themselves tend to be omitted, giving an under-representation of actual sugar content and thus a higher than expected final alcohol concentration.

For more information about sugar to alcohol conversion, please contact the AWRI helpdesk on helpdesk@awri.com.au or 08 8313 6600. GW