Calculation of Ethanol Production from Fermentation

This is an explanation of how students can calculate the amount of ethanol produced from their fermentations. The two things that must be measured are 1) the volume of the starting culture and 2) the volume of the gas produced during fermentation. To obtain the rate of fermentation, the volumes produced at specified times are also required.

First, we need to convert the volume of gas (CO$_2$) produced during fermentation into moles of CO$_2$.

The volume of a mole of gas depends on the pressure and the temperature. Standard values are easy to find, but be careful. The volume/mole is often provided for ‘standard temperature and pressure’ (STP): 22.4 liters/mole of gas. But STP is for a temperature of 0º Celsius and 1 atmosphere. What you really need is the volume/mole for RTP (room temperature and 1 atmosphere): 24 liters/mole. Calculating the moles of CO$_2$ produced is easier if you take the reciprocal: $1/24 = 0.042$ moles/liter.

Suppose your yeast experiments produce 500 ml (0.5 liters) of gas (CO$_2$) in the glucose fermentation. The volume produced is equivalent to

$$(0.5 \text{ liters}) \times (0.042 \text{ mole/liter}) = 0.021 \text{ moles of CO}_2.$$

If 0.021 moles of CO$_2$ are produced, how much ethanol was produced?

Glucose (a 6 carbon sugar) yields two ethanol molecules and two CO$_2$ molecules. For every ethanol molecule produced, 1 CO$_2$ gas molecule is released.

So if 0.021 moles of CO$_2$ are produced in our fermentation example, then 0.021 moles of ethanol are produced.

To find out the concentration of ethanol, we need to know the volume of the fermentation medium. If it was 500 ml (0.5 liters), then the concentration is 0.021 moles/0.5 liters = 0.042 moles/liter (or 42 mM) ethanol. What is the % ethanol?

In fermentations, ethanol percentages (% (w/v) (gm/100 ml)$^1$) are usually used, rather than concentrations. For example, beer has an alcohol content of about 4%: 4 gm/100 ml. To calculate % (w/v), you need to use the molecular weight of ethanol$^2$.

For our fictitious fermentation: $0.042 \text{ (moles/liter)} \times 46 \text{ (gm/mole)} = 1.93 \text{ gm/liter}$, or $0.193 \text{ gm/100 ml}$, which is equal to $0.193 \% \text{ (w/v)}$.

Of course, for your fermentation assignment, there are other questions that could be assigned. For example, how much ethanol would be produced if all the glucose fermented to ethanol and CO$_2$? Or what volume of CO$_2$? What is the time course of fermentation?

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$^1$ Ethanol has a lower density than water (it is 0.789 gm/ml at room temperature). During fermentation, the ethanol changes the density of the medium, usually measured with a hygrometer.

$^2$ The molecular weight of ethanol is 46 grams/mole. CO$_2$ is 44 grams/mole. Glucose has a molecular weight of 180.16 grams/mole.