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

$$(0.5 \text{ liters}) \bullet (0.042 \text{ mole/liter}) = 0.021 \text{ moles of } CO_2.$$

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 (moles/liter) • 46 (gm/mole) = 1.93 gm/liter, or 0.193 gm/100 ml, which is equal to 0.193 % (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.