INTRODUCTION

Fermentation is an anaerobic metabolic process that occurs in micro-organisms (fungi and bacteria) and produces energy by breaking down carbohydrates into simpler molecules. Fermentation was one of the first chemical processes to have been utilised (at least 5500 years ago) and its secrets intrigued a few great chemists (Lavoisier, Liebig, Pasteur). It wasn't until 1939 that the complex biochemistry of this deceptively simple reaction was finally worked out. Today, fermentation is a vital process used in diverse industries (brewing, baking, pharmaceutical).

AIM

The aim of this experiment is to plan an investigation that monitors the changes in mass occurring during fermentation.

PLANNING GUIDELINES

1 Choose appropriate glassware to contain the fermenting solution. Think about size and weight limitations. If your vessel is too large it will be unweighable. If your vessel is too small, the mass changes during fermentation will be negligible.

Prepare a 5% glucose solution. The volume of solution you prepare is determined by the size of the fermenting vessel. Add 1 g of dried yeast to the glucose solution and mix thoroughly. Add a pinch of Na_2HPO_4 or NaH_2PO_4 as a yeast nutrient.

2 Should your fermentation vessel be tightly capped? Study the fermentation equations given on the following pages for technical guidance.

3 How often should you monitor and record the changing mass during fermentation? Should you plot a graph of mass versus time?

Note: As a rough estimate, your fermentation will continue for at least 24 hours.

EXTENSION ACTIVITIES

Microscopic examination of yeast

In 1857, Louis Pasteur proved that yeasts are responsible for fermentation.

Examine these simple micro-organisms by observing a microscope slide of live yeast at 400X.

Testing for CO_2 and ethanol

Observe a demonstration fermentation apparatus with a gas outlet bubbling through limewater solution.

1 What changes were observed in the limewater solution during fermentation?

2 Write a chemical equation to explain the above observations.

3 Smell the contents of the fermenting apparatus. Is the odour of ethanol evident?

Distillation of ethanol

The fermented mixture can be distilled to produce much stronger alcohol. Pure ethanol boils at 78°C, so collect only the first few millilitres of distillate. Smell the distillate, then test its volatility and flammability.

QUESTIONS

1 Write the balanced chemical equation for the fermentation of glucose.

2 Identify the industrial method for ethanol production.

3 Write the chemical equation for the industrial synthesis of ethanol.

4 Describe some uses for ethanol.

4 **Extension experiment:** Students could distil their final fermented mixtures and collect and test the ethanol fraction (smell, volatility, flammability).

5 It is interesting to examine the elucidated fermentation equation:

$$C_6H_{12}O_6 + 2ADP + 2H_3PO_4 \rightarrow 2C_2H_5OH + 2CO_2 + 2ATP + 2H_2O$$

and compare it with anaerobic glycolysis in mammalian muscle tissue, which produces lactic acid (2-hydroxypropanoic acid) rather than ethanol:

$$C_6H_{12}O_6 + 2ADP + 2H_3PO_4 \rightarrow$$

$$2CH_3C(OH)HCOOH + 2CO_2 + 2ATP + 2H_2O$$

In each of the reactions above, ATP (adenosine triphosphate) is used as the energy source in the yeast cell and muscle tissue, respectively.

6 It is also interesting to compare the energetics of fermentation and respiration:

$$\Delta H_{\text{fermentation}} = -67.9 \text{ kJ mol}^{-1}$$

$$\Delta H_{\text{respiration}} = -2802.5 \text{ kJ mol}^{-1}$$

Clearly, fermentation is only viable for organisms with a low metabolic rate.