Research Article

Production of Bioethanol from Domestic Food Waste

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Abstract: *Domestic food waste has contributed significantly to global warming in all areas of the world. Particularly in Malaysia, it is estimated that 27% of cooked or prepared food waste is wasted, with starchy food being the most commonly wasted after being prepared. The conversion of domestic food waste to ethanol could become a reliable and sustainable solution to this problem. This process is further improved through hydrolysis of large starch molecules using enzymes, in order to increase the amount of fermentable carbohydrates which in turn produces a higher yield of ethanol after fermentation. After fermentation, ethanol is extracted from the mixture through simple distillation. The distillate was then subjected to an oxidation test and flammability test to prove that it contained ethanol. A test is also done to find the theoretical heat of combustion of ethanol to determine if ethanol is suitable to be used as biofuel for vehicles.*

Keywords: bioethanol; food waste; fermentation.

DOI: 10.5281/zenodo.10406360

1. INTRODUCTION

Over the years, domestic food waste has become a concerning problem in our fight against global warming. Large quantities of food waste are discarded from thousands of households across the country every day. These food waste will then end up at landfills, without being utilized and turned into useful products.

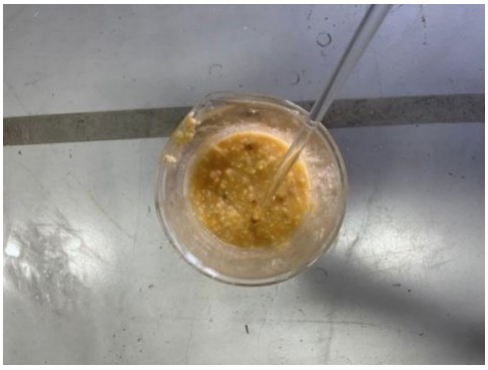
The bacterial decay of food waste in landfills produces methane, a potent greenhouse gas that is more harmful than carbon dioxide. The abundance of domestic food waste means that hundreds of gallons of methane are produced from these landfills.

Looking at the devastating impact that domestic food waste has on our planet, it is clear that we need to take immediate measures and come up with methods to make use of domestic food waste in order to prevent them from ending up at landfills and to overcome their harmful effects towards the planet.

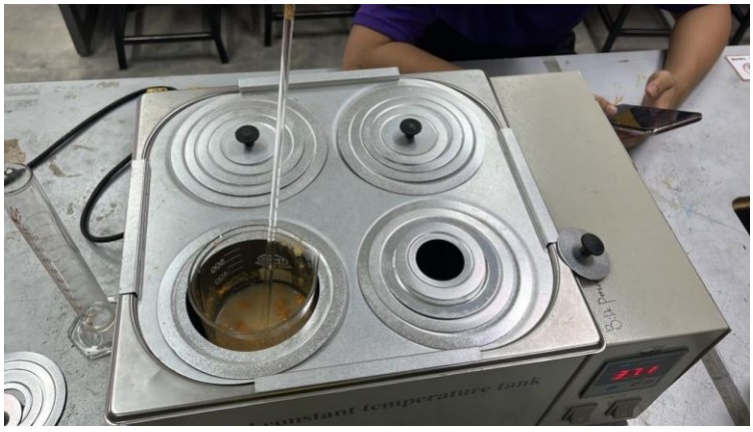
2. METHOD & MATERIAL

2.1 Enzyme hydrolysis

1. 168g of food sample is grounded using pestle and mortar.
2. The crushed food sample is added into a 500cm³ beaker.



3. 200cm³ of distilled water is added to the beaker.
4. 15cm³ of 5% amylase solution is added to the beaker.
5. The mixture is stirred well using a glass rod.



6. The mixture is heated using a thermostatic water bath at a constant temperature of 37°C for 1 hour.

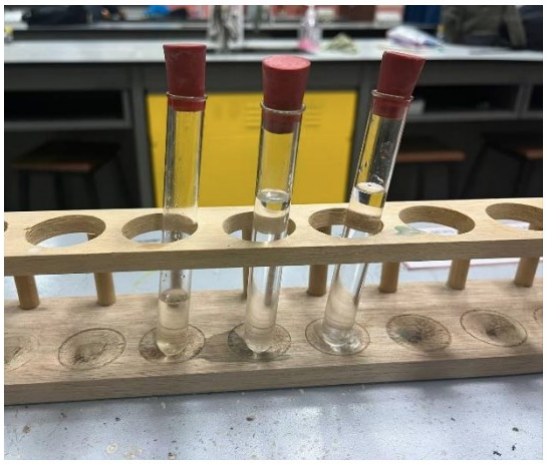
2.2 Fermentation

1. The mixture is heated using a Bunsen burner until boiling.
2. The mixture is allowed to cool down.
3. The mixture is added to a conical flask.
4. 50cm^3 of 5% yeast solution is added to the mixture.
5. A layer of paraffin oil is added to the mixture.
6. The conical flask is closed using a rubber stopper with rubber tubing.

7. The end of the rubber tubing is submerged in a beaker containing limewater.
8. The mixture is left at room temperature for 48 hours.

2.3 Extraction

1. Simple distillation apparatus is set up.
2. The mixture is filtered.
3. The filtrate is added to the round-bottomed flask.
4. The round-bottomed flask is heated using a Bunsen burner.



5. The distillate is collected and tested.

2.4 Heat of combustion of ethanol

1. 200cm³ of distilled water is poured into a copper can. Initial temperature of the water is recorded.
2. A spirit lamp is filled with ethanol. The mass of the spirit lamp and ethanol is measured and recorded.
3. The wick of the spirit lamp is lit and the distilled water is heated until its temperature increases by 30°C.
4. The flame is put out and the mass of the spirit lamp and ethanol is measured and recorded.

2.5 Oxidation test of distillate

1. 5cm³ of distillate is added to a boiling tube.
2. 5cm³ of acidified potassium dichromate(VI) solution is added to the boiling tube.
3. 10 drops of concentrated sulphuric acid is added to the boiling tube.

4. The solution is heated using a hot water bath for 10 minutes.
5. The colour change of the solution is observed and recorded.
6. Steps 1-5 are repeated with acidified potassium manganate(VII) solution.

2.6 Flammability test of distillate

1. The distillate is poured into an evaporating dish.
2. The distillate is lit.

3. A piece of paper is held at the top of the evaporating dish.
4. The colour of the flame and soot formation is observed and recorded.

3. FINDINGS

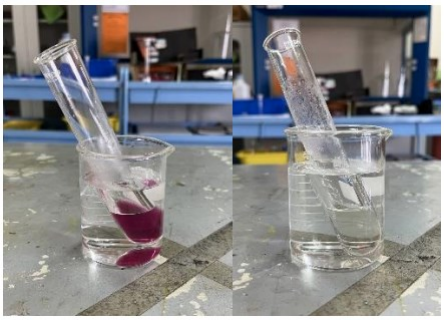
3.1 Data and observation

Data	Value
Mass of raw material used	300 g
Volume of distillate obtained	38 ml
Initial mass of spirit lamp	241 g
Final mass of spirit lamp	239 g
Mass of ethanol	2 g
Heat of combustion per gram of ethanol	12.6 kJ/g

3.2 Oxidation test

- The solution with acidified potassium dichromate(VI) changes colour from orange to green.

- The solution with acidified potassium manganate(VII) changes colour from purple to colourless.



3.3 Combustion test

The distillate burns with a blue flame without soot.

4. DISCUSSION

The food sample was first grounded to break large chunks of food into smaller particles and allow them to be contained in the distilled water and form a mixture. Distilled water is added to allow the enzymatic action of amylase and anaerobic respiration of yeast during fermentation. Amylase enzyme is then added to the mixture. This is an important step as it helps to break down large chains of starch, in the form of amylase, into fermentable sugars such as glucose than can be turned into ethanol by yeast. This process can be represented through the chemical equation:

$$nC_6H_{10}O_5 + nH_2O \rightarrow nC_6H_{12}O_6$$

This mixture is then heated at 37°C to increase the rate of enzymatic action as it is the optimum temperature for amylase enzyme.

The mixture is then boiled to remove dissolved oxygen. It is allowed to cool down in order to ensure that the yeast does not die when added to the mixture. Paraffin oil is added to the mixture after addition of yeast solution to prevent oxygen from the atmosphere to dissolve. This is done to create an anaerobic environment that will allow the anaerobic respiration of yeast to produce ethanol. This process is catalysed by the enzyme zymase which is released by the yeast. The chemical equation for this process is as follows:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

The conical flask is closed with a rubber stopper. Rubber tubing is connected to the rubber stopper and submerged in limewater to relieve the pressure in the conical flask due to the build-up of carbon dioxide which is a product of fermentation. This is also done to prevent oxygen from the atmosphere to enter and dissolve in the solution, preventing the oxygen concentration from increasing. The limewater also turned cloudy, confirming the presence of carbon dioxide.

The extraction of ethanol is done by simple distillation. This will cause ethanol in the solution to boil and vaporise. The vapours of ethanol will go through the condenser. The continuous stream of water will cause the vapour to cool down and condense into liquid form.

The theoretical energy content ethanol obtained is found by finding the heat of combustion of ethanol through the formula:

$$Q = mc\Theta$$

Through this method, it is found that the energy content of ethanol is 12.6kJ/g. This can be compared with the energy content of gasoline, which is 44.4kJ/g and the energy content of diesel, 46.2kJ/g. It can therefore be concluded that ethanol has a relatively lower energy content compared to fossil fuels such as gasoline and diesel. This means that a large mass of ethanol is needed to be able to power vehicles.

Through the flammability test, it is observed that the paper burns when the distillate is lit. This proves that ethanol was produced by the distillation process and that methods used in the project were able successfully to produce ethanol.

5. CONCLUSION

The fermentation of food waste produces ethanol that can be processed further to produce a variety of products such as vehicle biofuel and hand sanitizer. The distillate obtained mostly consists of a mixture of ethanol and water, amongst other components in miniscule amounts. The pre-treatment of the food sample through hydrolysis using amylase enzyme increases the yield of ethanol obtained significantly. This process is therefore proven as a method to utilize domestic food waste and is a sustainable method to produce ethanol.

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