# <u>Final Report</u>

## *Ecofriendly Synthesis of Bioethanol from tapioca plant (Manihot esculenta)*

**Group 01-01**

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## Content Overview

## 1. Abstract

Energy consumption is set to increase for the foreseeable future. With growing awareness of global warming and climate and the need to reduce reliability on non-renewable sources of fuel, the search for a cleaner and more sustainable source of energy is picking up. Tapioca *(manihot esculenta)* is high in starch and very easy to cultivate. This study aims to determine the effectiveness of tapioca in the production of biofuel as well as best methods to obtain the maximum amount of biofuel from the biomass. To achieve the former, the experiment involves the comparison of tapioca against other common biomasses such as sugarcane *(saccharum officinarum)*. The study prepared 200g of each set of biomass. The experiment was repeated three times for better reliability. Each of the 6 samples was distilled to 50ml. 15ml of the extract was poured into a test tube and an ethanol sensor was used to detect the concentration of the ethanol in the air above the aqueous solution. The study found that tapioca extract had an average of 4.72% of ethanol while the sugarcane extract had 7.08% on average. The total amount of ethanol yield was calculated by multiplying the percentage by 50ml. The variance of the tapioca plant and sugarcane plant was 0.0924 and 0.754 respectively. A T-Test, specifically a two-sample unequal variance (heteroscedastic) test with two-tailed distribution, was performed. The value of 0.1313637552 was given indicating that the values do not vary signifcantly. Hence, The study concludes that although the tapioca plant may be slightly less effective than sugarcane, it can be applied in the biofuels industry as an alternative source of biomass.

## 2. Introduction

### 2.1. Literature Review

**Energy consumption**

Global energy consumption is increasing rapidly especially in less economically developed countries. The United States Energy Information Administration (EIA) projects a 54% increase in global energy consumption. Most of the growth is attributed to non-OECD (non-Organization for Economic Cooperation and Development) countries, where demand is driven by strong economic growth (EIA, 2013). Non-renewable energy sources such as coal and petroleum still make up the large majority, with around 75% of all primary energy used are derived from them, based on statistics (IHS Markit, 2019). Inevitably, these sources will be depleted. This leaves countries scouring for the next source of energy to feed both domestic and economic demands in their country.

**Implications of fossil fuel**

Burning fossil fuel produces greenhouse gases such as carbon dioxide and nitrous oxide have been directly linked to global warming and climate change. The greenhouse gas traps heat in Earth's atmosphere, disrupting countless ecosystems and natural habitats across the globe. In 2009, during the Copenhagen Climate Change Conference, (UNFCCC, 2009) the international target was to prevent global temperatures exceeding more than 2°C (Tomilola, et. al., 2009). To meet this target, the world can only use approximately 20% of its oil, coal and gas reserves (McKibben, 2012). Also, burning fossil fuels is related to air pollution. Long term exposure to microscopic matter is related to coronary events (Cesaroni, et. al., 2014) which may lower life expectancy by as much as 15 years (Guo, et. al., 2013).

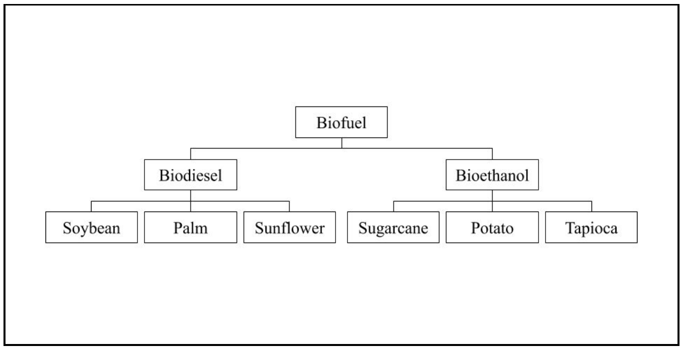
**Biofuel**

Biofuel is a form of renewable energy and can be replaced easily and indefinitely. It uses waste or plant matter to obtain energy and has a lower carbon footprint as compared to fossil fuels (Demirbas, 2008). It is seen as one of the viable solutions to our increasing energy demand. Biofuel has many positive attributes summarised in the table below.

| **Conventional fuel*** | **Biofuel** |
|---|---|
| High greenhouse gas emissions. | Low greenhouse gas emissions. |
| Produces microscopic particles. | Little to no contribution to environmental pollution |
| Non-renewable source of energy. | Renewable source of energy. |

** Conventional fuel includes coal, crude oil, natural gas etc.*

**Table 1. Advantages of biofuel compared to current sources of energy. *Adapted from (Demirbas, 2008) and (John, et. al., 1998).***




Biofuel can be grouped into two subsets – biodiesel, and bioethanol. The sources are illustrated in the diagram below.

**Fig.1. Table illustrating resources of biodiesel and bioethanol.** ***Adapted from (Demirbas, 2008) and (John, et. al., 1998).***

**Tapioca**

Tapioca is widely produced in areas with warm climates, typically along the equator. Tapioca is one of the most efficient producers of carbohydrates and energy among all food crops (Long, et. al., 2020).

| Crop | Amount of calories per hectare per day |
|---|---|
| **Tapioca plant** | 250 000 |
| **Corn** | 200 000 |
| **Rice** | 176 000 |
| **Wheat** | 110 000 |

**Table 2. A table illustrating the amount of calories produced by crops per hectare per day.** ***Adapted from (Long, et. al., 2020).***

In Nigeria alone, about 38 million metric tonnes (MT) of tapioca is produced per annum; a figure expected to double by 2020 (EUCORD, et. al., 2006). Other countries such as Thailand and Brazil also produce a substantial amount of tapioca, producing around 31.6 million and 17.6 million in 2018 respectively (FAOSTAT, 2018). To be viable in bioethanol production, the crop should be a high yielding, fast growing, with a cell wall that is easy to break down and requiring relatively small energy inputs for its growth and harvest (Waclawovsky, et. al., 2010). The study highlights the massive cultivation of tapioca across many countries and believes that tapioca can be used as a biomass more actively and on a larger scale.

Besides being an efficient producer of carbohydrates, tapioca can also tolerate a wide range of unfavourable conditions. Tapioca shows high productivity in favorable conditions and tolerance to stressful environments, such as prolonged water stress and marginal low-fertility soils (El-Sharkawy, 1993). A tolerant crop can be easily farmed in many places. Should tapioca be found to be a feasible biomass, production can be scaled up to meet demand. Therefore, the study sees great potential in applying this versatile crop as a biomass.

**Sugarcane**

On the other hand, sugarcane has been widely seen in the biofuel industry. Its high sucrose content makes it a viable biomass. A sugarcane plant can contain around 15% of sucrose (Pereira, et. al., 2017). This percentage may vary from species to species and may also be affected by the area where it was cultivated. Brazilian bioethanol from sugarcane is the most successful case at the world level because of its low cost and low level of greenhouse gas emissions (Furtado, et. al., 2011).

## 2.2. Scope

The scope of this study is limited to bioethanol and the 2 biomasses, tapioca and sugarcane. The paper will only cover materials and methods used in the extraction of the alcohol, ethanol, from these biomasses. The study hopes that it can raise awareness of tapioca's potential in the biofuel industry and would also like to highlight biofuel's advantages as an energy source for the future.

## 2.3. Purpose & Objectives

The aims for this study are **(a)** to find out if a tapioca plant can be an effective source of biofuel by comparing it to sugarcane, which are commonly used sources of biofuel, and **(b)** to study the effective ways to maximise the potential of tapioca in biofuel production. For the former, factors such as its cost effectiveness and whether it can be replicated on a larger scale will be considered to gauge the overall effectiveness of tapioca in biofuel production.

### 2.4. Hypothesis

The study hypothesised that the tapioca plant will be as effective as a biomass such as sugarcane, and will be suitable and sustainable in the future production of biofuel.

## 3. Materials and Methods

### 3.1. Materials

The study will require different materials to produce ethanol ($C_2H_5OH$) from the different biomass. 600g of sugarcane and tapioca was purchased from neighbouring supermarkets and wet markets. The table below summarises the necessary materials.

| Materials | Equipments |
|---|---|
| 0.15g of α-amylase (divided into 3 samples) | Beakers, test tubes, and conical flasks |
| 48g of baker's yeast (divided into 6 samples) | Blender |
| 600g of tapioca (divided into 3 samples) | Centrifuge |
| 600g of sugarcane (divided into 3 samples) | Ethanol Sensor |
| | Fractional Distillation Set-up |
| | Freezer |
| | Hot Plate Stirrer |

**Table 3. Equipment and chemicals needed to extract ethanol from the biomasses.**

### 3.2. Methods of extraction

#### 3.2.1. Tapioca

The dark brown and pink layer of tapioca (200g) was deskinned before it was cut into cubes. 200g of tapioca cubes were mixed with water and blended together.


**Fig.2. Raw tapioca plants were de skinned and cut into cubes. 200g of tapioca plant was blended with DI water.**

After storing the mixture in a plastic bag, it is left in the freezer at 4°C to prevent fungi growth. Next, each sample was heated at 80˚C until it became colloid (about 30 minutes). 0.5ml of DI water was added to 0.05g of powdered a-amylase and was added into each of the samples. This is to convert starch into glucose. After letting the amylase break down the mixture, the samples were centrifuged at 8000rpm for 10 minutes and the supernatant was extracted.

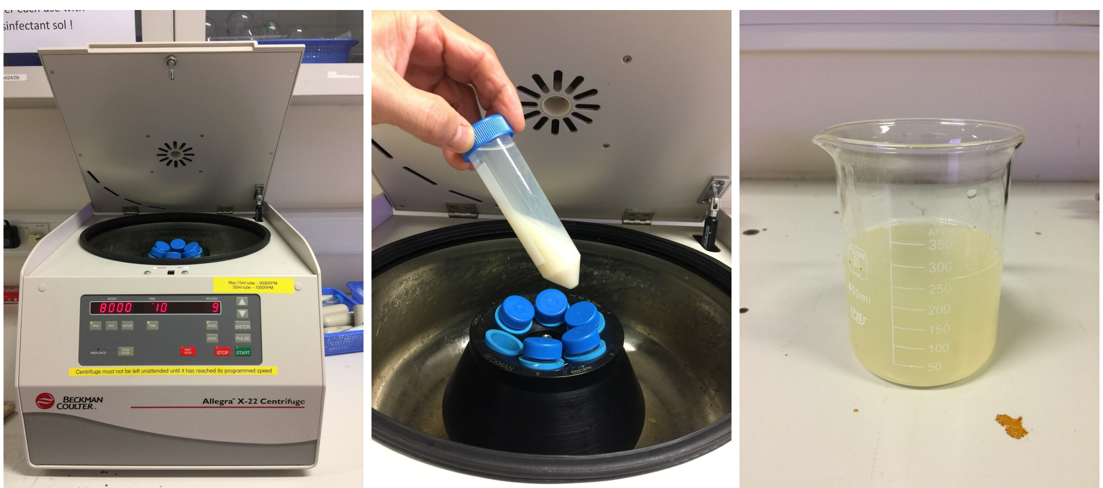



**Fig.3. The pictures above illustrate the centrifugation process.**

8g of Baker's yeast was added to the 3 samples to ferment glucose into ethanol (Farah, 2012). Ethanol is produced by the fermentation of monosaccharide such as glucose and fructose.

**Chemical Equation:** $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$


**Fig.4. 8g of yeast was added to the solution and stirred well. Around 250ml of the mixture was left after fermentation.**

### 3.2.2. Sugarcane

200ml of sugarcane juice was bought. 8g of Baker's yeast was added into each of the samples and left to ferment for 2 days.

**Fig.5. Around 200g of the mixture was left after fermentation.**

### 3.3. Data Collection

All the samples were transparent and had an alcoholic smell to it. 15 ml of each sample was poured into a container and an ethanol sensor was used to detect the percentage of ethanol in every sample.

**Fig.6. The pictures show the 6 samples after distillation (left). An ethanol sample was used to measure the concentration of ethanol in each sample (right).**

## 4. Results and Discussion

### 4.1. Raw Data

| | Sugarcane plant | | | | Tapioca Plant | | | |
|---|---|---|---|---|---|---|---|---|
| **Samples** | **1** | **2** | **3** | **Mean** | **1** | **2** | **3** | **Mean** |
| **% of ethanol in extract** | 6.84% | 5.47% | 8.92% | 7.08% | 4.83% | 5.26% | 4.06% | 4.72% |

**Table 4. Readings gathered from the sensor. The mean of the 3 samples was calculated.**

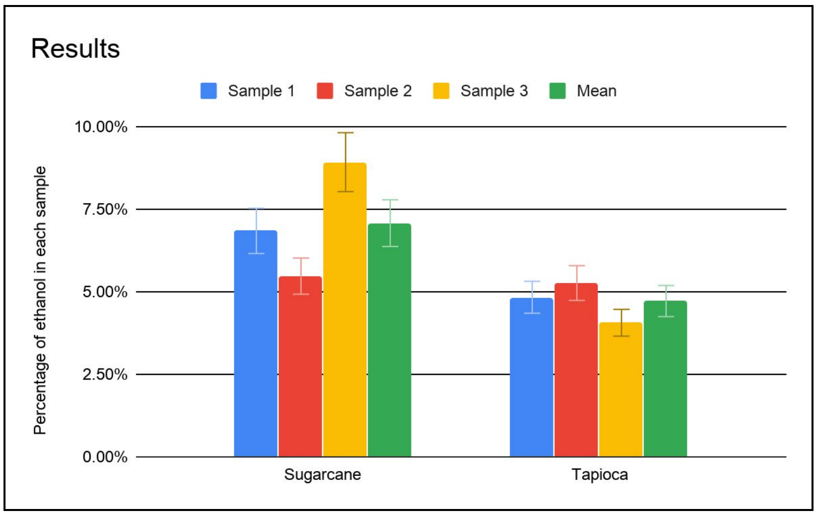



**Fig. 12. Bar chart with error bars illustrating test results.** The sugarcane plant had a higher concentration of ethanol yield as compared to the tapioca plant.

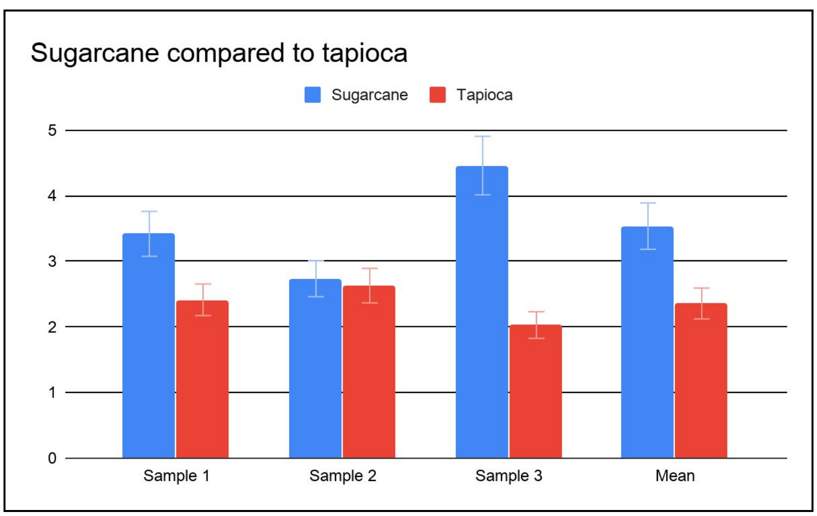



**Fig. 13. Percentage of ethanol recorded by ethanol sensor was multiplied by 50ml, to calculate amount of ethanol in each sample.**

However, the ethanol yield for the tapioca plant was quite close to sugarcane, especially Sample 2 which was just slightly less than sugarcane.

### 4.2. T-Test

A T-Test was also conducted to determine how much the value obtained varied. A two-sample unequal variance (heteroscedastic) test with two-tail distribution was performed. The data sets were the amount of ethanol produced by the two biomasses. A score of 0.1313637552 was obtained, suggesting that there is no significant difference between the two data sets. Hence, it is a possibility that the tapioca plant can be a good replacement for sugarcane.

### 4.3. Comparison to other studies

| | **Our results** | **Results from other research** |
|---|---|---|
| Tapioca Mass and Ethanol Generated | 200g of tapioca generated 2.27 ml of ethanol | 5000g of tapioca generated 310ml of ethanol |
| Ratio (Ethanol generated/Mass) | 2.27ml ÷ 200g=1.13%ml/g | 2210ml ÷ 35000g = 6.31%ml/g |

**Table 5. Our results compared to similar studies. Adapted from (Adelkan, 2010).**

Our study yielded less ethanol per biomass as compared to other studies. This is due to our sources of error (refer to *4.5. Sources of Error & Weaknesses*) and differences in methods used.

### 4.4. Discussion

| | Tapioca | Sugarcane | **Tapioca** effectiveness compared to **sugarcane** |
|---|---|---|---|
| Mean ethanol yield in each sample | 2.27ml | 3.54ml | 1.13 ÷ 1.77 ✕ 100% = **64.1%** |
| Yield from raw materials (%) | 1.13% | 1.77% | |

**Table 6. Processed results showing average ethanol yield for tapioca plant and sugarcane.**

According to the results, the tapioca plant is less effective compared to the sugarcane plant with only a 64.1% effectiveness compared to sugarcane. However, the price of the tapioca plant is generally lower than sugarcane. In the case of this study, $2 can buy 1Kg of tapioca while only

600ml in the case of sugarcane. According to Tridge (n.d), 1Kg of sugarcane can cost USD 0.51. On the other hand, according to the Thai Tapioca Starch Association (2020), the domestic price of tapioca can be as low as 12.90 Baht (USD 0.41)/Kg. As a result, the tapioca plant can be applied in developing countries where prices for it are low to help in further development.

### 4.5. Sources of Error & Weaknesses

**Sources of Error:**

a) The ethanol sensor can only measure the concentration of ethanol in the air above the aqueous solution.
b) Sufficient time may not have been given for the samples to ferment.
c) Mass of fibre was considered in the mass of the sample for tapioca but not for sugarcane.

**Weaknesses:**

a) Physical properties such as distillation range, viscosity, and electrical conductivity were not considered (Ademiluyi, et. al., 2013).
b) Specific enzymes *(e.g. Termamyl SC*, *Dextroxyme)* which are of higher quality and have heat resistance could not be sourced.

## 5. Application

### 5.1. Application of tapioca in the biofuel industry

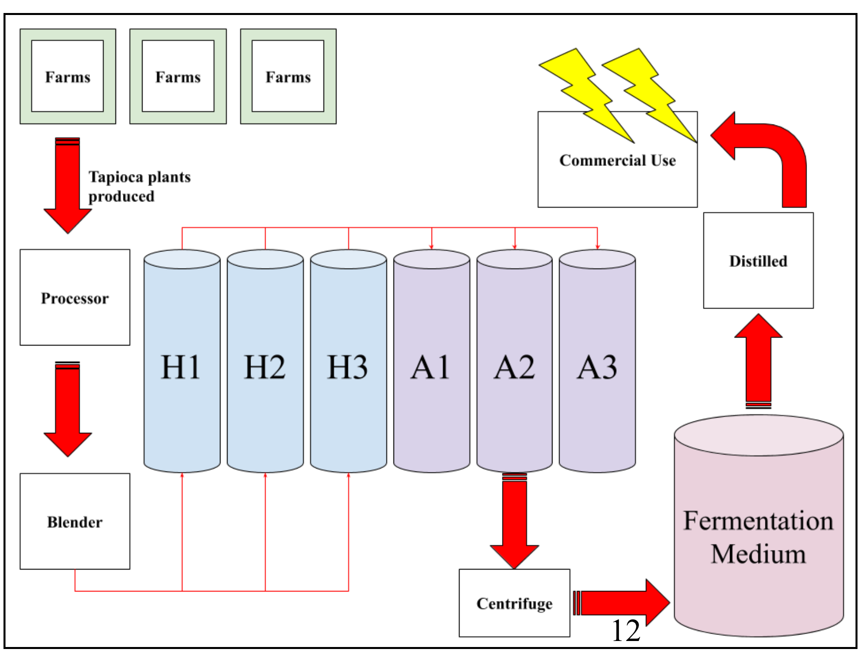



**Fig. 14 Proposed method to synthesize bioethanol from tapioca on a greater scale. The blue and purple barrels represent the heating process and amylase process respectively.**

### 5.2. Future application

In the future, studies can further test the quality of bioethanol extracted from tapioca by carrying out tests on its flash point, viscosity, distillation range and electrical conductivity as compared to other biomasses (Ademiluyi, et. al., 2013). Studies could also test a wider range of biomass such as maize or algae which have shown great potential too.

## 6. Conclusion

The study found that although sugarcane had a slightly better bioethanol yield, tapioca is still a viable source of biofuel. Future research can look into whether tapioca is as if as compared to other biofuels such as biodiesel. Furthermore, other studies can see if replication on a larger scale is feasible.

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