Experimental Study of Bioethanol Production as Fuel from Salacca Zalacca Waste and Coconut Water Waste Combination

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Abstract. The process of burning fuel from the engine produces exhaust emissions that have a negative impact on the environment. Bioenergy as biofuel needs to develop to reduce emissions. Biomass is one of the bioenergy sources and has high potential to be used as a liquid fuel; some of the available biomass is a waste of salacca zalacca fruit and coconut water waste. In the process of bioethanol production, several mechanical factors influence it, including the energy needed for the distillate process, bioethanol mass flow rate and the ethanol content it contains. This research aims to analyze the energy needed for the distillation process to reach 85 OC, calculate the mass flow rate and determine the ethanol content of this fuel. An acquisition parallax microcontroller device is installed on the distillation vessel and condenser. This tool is used to record changes in temperature during the distillation process. From the experiments that have been done, the total energy needed for the distillation process is 346.32 W, bioethanol mass flow rate is 0.0665 kg /s.

Keywords: Bioethanol, Salacca Zalacca, coconut water, energy.

1. Introduction

Increased human activity in the field of industrial, fabrication, vehicles and other activities involving the combustion of petroleum fuels has led to a decrease in petroleum reserves in the world [1]. On the other hand, combustion of petroleum fuels either in external combustion or internal combustion engines causes the formation of exhaust emissions, CO, CO2, NOx, HC and negatively impact the environment (global warming), health and global economy [2]. This has prompted humans to immediately switch the consumption of petroleum fuels to alternative fuels [3]. Biomass is an alternative fuel and can be as fuel in the gasoline engine after going through biochemical and thermochemical processes [4]. That the biomass potential undeveloped reach to 99%, especially in Indonesia [5].

Various studies have given a contribution produces some alternative fuel from various of biomass waste. It’s clean and environmentally friendly and relatively cost effective [6]. There are several of biomass from agree cultural waste is abundant. The potato waste that becomes an environmental problem is used as raw material for bioethanol [7-8]. In addition to potatoes, sugar cane is also an option for bioethanol feedstock [9], some other biomass can be used as bioethanol feedstock such as: pineapple [10], alga [11], carbohydrates with syngas fermentation [12], hydrolysis [13], newspaper waste [14], and others.

There are two variations of liquid fuel that can be obtained from biomass derivatives such as biofuel for diesel engines such as fuel from palm oil [15], castor oil [16], and others [17]. There are also biofuel fuels for gasoline engines such as bioethanol, diethyl ether [18], hydrogen [19] and others. Based on
several factors’ considerations of these two fuels each has advantages and disadvantages. Among other factors are the cost production [20], value of caloric, octane and other factors [21].

Salacca zalacca and coconut water also a biomass that can grow easily in the tropics, as well as coconut that in fact still has a close relationship with salacca zalacca. Salacca zalacca and coconut harvest cycles also have similarities, both of which can continue to bear fruit throughout the year, but at certain times these two plants experience the harvest season and the crisis. At harvest time, salacca zalacca cannot be sold out all in the market, leaving a post-harvest problem. The harvest problem is not worth selling because the quality is low so increase the volume of waste. Also, the coconut water is obtained from a coconut seller who sells coconuts for food supplies for households. Every coconut is averaging 0.5 liters of water contained and disposed. Based on its phenomenon, the authors try to take and utilize to be processed into a mixture of fermentation of salacca zalacca waste and coconut water waste.

2. Research objectives:
During the distillation process, the phenomenon of convection heat transfer and the power needed to heat the solution to 85 °C on the distillation vessel is unknown. In addition, to analyze these phenomena, this aims of this study is to
i. Determine the characteristics of bioethanol from a mixture of the two ingredients in question.
and also to determine:
ii. Analyze how much power is needed to heat the distillation chamber up to 85 °C and how much the convection heat transfer
iii. To study the characteristics of bioethanol, which is derived from various biomass waste materials

3. Methods
3.1. Experimental setup
Distillation is a phase separation process using the boiling point of the phase to be separated by using heat energy. The heat energy needed to increase the fluid temperature from 29.5 to 85 °C theoretically is calculated by equation (1). The heat source is given through heating elements which are mounted on distillation with specifications as in table 1

\[ q = hA (T_w - T_\infty) \]

Table 1. Properties of heater element [22]

| Heater element | Max. Power (W) | h (W/m²°C) | Diameter (m) | Length (m) | Area m² |
|----------------|----------------|------------|--------------|------------|---------|
| Aluminum       | 230            | 5.00E+03   | 1.50E-03     | 1.33E-01   | 6.24E-04 |

In this study, the authors build a distiller with a very simple design, but still consider its functions. This is done with the consideration that the distiller plan is intentionally built for in rural areas, resulting in minimal maintenance costs and operating costs [23].

3.2. Raw materials
Bioethanol is a mixture of 1:1 of zalacca and coconut water, which is mashed using a blender machine into a fermentor solution. The properties of the fermentor solution is the average amount of both materials as in table 2 below.
Table 2. Raw material of bioethanol

| Ingredient            | ρ (kg/m³) | Alcohol content (%/vol) |
|-----------------------|-----------|-------------------------|
| 1 Salacca Zalacca    | 1066.7    | 70                      |
| 2 Coconut water       | 1030      | 10                      |
| 3 mixture (average)   | 1048.35   | 40                      |

3.3. Mass flow rate

The bioethanol mass flow rate is a condensed vapor mass per time change during the distillation process, mathematically written in equation (2).

\[ m = \frac{m_{\text{cond}}}{r} \left( \frac{kg}{s} \right) \]

3.4. Bioethanol content yield

In general, bioethanol content can be known by using a measuring instrument, in this study refractometer is used to determine the bioethanol content in units of %. The drop samples of bioethanol putted in the prism assembly and then look at the eyepiece. Refractometer seen in figure 1.

![Refractometer](image)

Figure 1. Refractometer

3.5. Measurement Tools and Experimental Apparatus

The measurement tools installed on the distillation chamber to record the distillation temperature process and connected by parallax acquisition microcontroller data PLX-DAQ using ATmel ATmega, it has specification showed in table 3.

Table 3. Specification of measurement tools

| Device   | Flash | EEPROM | RAM   | General Purpose I/O pins | 16 bits resolution PWM Channels | Serial USARTs | ADC Channels |
|----------|-------|--------|-------|--------------------------|--------------------------------|----------------|--------------|
| ATmega2560 | 256KB | 4KB   | 8KB   | 86                       | 12                             | 4              | 16           |

Five measurements of the k type thermocouple are allocated to records the temperature during the distillation process. The thermocouples range temperature of 0 - 1100 °C. Table 4 shows the identify of some of the variables recorded.
Table 4. the temperature measurement of the distillation process

| Variable | Identify | Explanation |
|----------|----------|-------------|
| T1       | V in     | Vapor into the condenser |
| T2       | V out    | Vapor out the condenser |
| T3       | W in     | Water into the condenser as cooling fluid |
| T4       | W out    | Water out of the condenser after cooled the condenser |
| Tdist.   | T distillation | Temperature of distillation chamber |

Experimental Apparatus in this study, especially to distillation process is shown in the figure 2 belows.

![Figure 2. Experimental apparatus and measurement](image)

Fermentation solution put into a distillation vessel of 500 mL, then heated for 1125 seconds at 85 °C. The solution vapor flows through the pipe to the condenser and the vapor is condensed. Sensor temperature is installed at 5 measurement points which are at the distillation vessel, the vapor inlet into the condenser, vapor outlet from the condenser, cool water inlet into the condenser and cool water outlet from the condenser.

4. Result and Discussion
After the experiment conducted, energy needed to heat up fermentation solution was calculated, temperature distillation during process was recorded by PLX-DAQ. The mass flow rates during the distillation process, quality and calorific of bioethanol were measured.

4.1. Energy to heat up
The energy needed for distillation to reach 85 °C is calculated using equation 1, then the result is 173.16 W. This is due to the two heater elements are installed in a distillation vessel so the total energy becomes 86.58 W each heater element. The detail can be seen in table 5.

Table 5. Calculation of distillation energy

| h (W/m²°C) | Area (m²) | Tw (°C) | Ts (°C) | Q (W) |
|------------|-----------|---------|---------|-------|
| 5000       | 6.24E-04  | 85      | 29.5    | 173.16|
4.2. Distillation process
The fermentation solution of 500 mL was put into a distillation vessel, then the distillation vessel was heated from 29.5 °C to 85 °C. Vapor flows through a 2.5E-2 m diameter pipe to a condenser at a temperature of 80 °C, temperature is recorded as long as the distillation process lasts 1125 seconds using the parallax microcontroller data acquisition (ATmel 2650), can be seen in figure 3.

![Distillation Process](image)

**Figure 3.** Distillation process

4.3. Mass flow rate
The bioethanol mass flow rate at the distillation process for 1125 seconds, calculated using equation (2), measured the mass of bioethanol directly by measuring the digital scales of time unity. Then the bioethanol mass flow rate is 0.0655 kg/ s.

4.4. Bioethanol content
After the distillation process is finished, the output of bioethanol fuel yielded and the bioethanol content determined by refractometer. The prism assembly shows of 40% bioethanol content. It can be seen in figure 4 that if we retest ethanol content in each raw material, the final results show a very good number compared to the ethanol content of a mixture of zalacca and coconut water.
Therefore, for the next study is to reduce and measure the bioethanol heating value of these two ingredients. It showed in table 6.

Table 6. Comparison ethanol content

| Ethanol content of salacca zallacca (%) | Ethanol content of coconut water (%) | Average (%) | Distilled (%) |
|----------------------------------------|-------------------------------------|-------------|---------------|
| 70                                     | 10                                  | 40          | 40            |

5. Conclusion
Biomass has the big potential as a biofuel source, in addition to the abundant amount of raw material from agricultural waste it is also a source of environmentally friendly fuels, bioethanol is a liquid fuel that has physical properties such as fossil liquid fuels, so the user does not need to change engine geometry. In the bioethanol production process, there are several mechanical factors that influence it, the energy needed to heat up to 85 °C, the amount of mass flow rate and ethanol content that is owned by the fuel. The energy needed for distribution reaches 85 °C is 346.32 W, bioethanol mass flow rate is 0.0655 kg / s and ethanol content is obtained 40%.

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