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To cite this article: Ansar *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **819** 012051

IOP Conf. Series: Earth and Environmental Science **819** (2021) 012051 doi:10.1088/1755-1315/819/1/012051

The distillation process of palm sap (*Arenga pinnata* MERR) to produce bioethanol

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Abstract. Aren palm (*Arenga pinnata* MERR) is a type of palm tree that grows in tropical forests, especially in South and Southeast Asia. There are 3000 species of palm and they are categorized as multipurpose trees because they were used as raw materials for various products, such as brown sugar, palm syrup, palm wine, vinegar, alcohol, and bioethanol. This study aims to examine the distillation process to produce bioethanol from aren palm. The research sample was obtained from local farmers in Sasaot Lombok, Indonesia. The process used to produce bioethanol is multilevel distillation. The raw materials are first fermented using yeast, charcoal, and lime with a variety of compositions. The bioethanol produced is used as a substitute fuel for a 4-stroke motorbike engine. The results showed that the composition of the fermentation mixture of 250 grams of yeast, 100 grams of charcoal, and 100 grams of whiting produced the highest levels of ethanol, namely 93%. This level of ethanol cannot be used in a 4-stroke motorbike engine properly because the motor rotation is unstable.

1. Introduction

Sugar palm is a plant that has long been known as a source of ethanol found in sap [1]. This sap is a sweet liquid obtained from flower bunches by tapping [2]. The sugar content of palm sap ranges from 6-16% [3]. Sugar palm has great potential to be used as a source of raw material in ethanol production [4]. If the sap is left alone, it will turn into tuak with 4% ethanol content [5].

Palm sap contains several nutrients including carbohydrates, proteins, fats, and minerals [6]. The freshly dripping sap from flower bunches has a pH of around 7 (neutral pH), but the influence of the surrounding conditions causes the palm sap to be easily contaminated and fermented so that the sweet taste of the palm sap quickly turns sour (pH decreases) [7].

Some researchers have processed palm sap into bioethanol, but the technology used is still very simple, so it cannot produce ethanol levels above 95% [8]. Ansar et al. [9] argued that to obtain absolute ethanol with 99% alcohol content, it is necessary to carry out multilevel fermentation using a molecular sieve. The critical point of processing palm sap into bioethanol lies in the treatment before it is processed. Palm sap is easily damaged by environmental conditions during tapping and transportation to the processing plant as well as damage due to the fermentation process [10].

The search for bioethanol as a fuel source has been developed in many countries [11]. Bioethanol production in the United States was developed from corn [12]. Brazil has been developing bioethanol from sugarcane since 1925 [13]. China and Thailand have developed bioethanol from cassava [14]. South Korea has also been developing bioethanol since 2002 [15].

Currently, bioethanol has been used as a substitute for fossil fuels [16]. The use of bioethanol as a fuel mixture is thought to save the earth from global warming [17]. The development of bioethanol for alternative fuels needs technology and market support to obtain optimal economic benefits [18]. Therefore, this study aims to carry out a multilevel distillation process to produce bioethanol from palm sap which can be used as a motor vehicle fuel substitute.

2. Research methods

The main ingredient used is palm sap without preservatives purchased from farmers in Sesaot West Lombok, NTB. This palm sap starts tapping at 17.00 WITA (afternoon) until 07.00 WITA (morning). Additional ingredients are coconut shell charcoal and whiting. While the equipment used is a set of distillation tools with a capacity of 1000 ml, thermometer, thermodynamic, desiccator, pycnometer, Erlenmeyer tube, a motorbike unit, tachometer, alcoholmeter, and measuring cup.
The research stages are as follows:
1. The fermentation process

The fermentation process is carried out by leaving the palm sap in a fermentation container with a mixture of fermipan yeast (Saccharomyces cerevisiae), coconut shell charcoal, and lime for 3 and 6 days.
2. Initial distillation

The initial distillation was carried out using a distillation tool without temperature regulation. The time used for this initial distillation process is also not determined but refers to the 50 ml pycnometer. When the pycnometer is fully charged, the distillation process is complete.
3. Final distillation

The results of the distillation process are carried out to separate ethanol from the fermented solution by heating the solution by maintaining the heating temperature at the boiling point of ethanol, which is 78 °C. The evaporation results are flowed into the pipe and condensed, then return to liquid ethanol.
4. Distillate results

The results of the distillate were stored in the Erlenmeyer, and then the distillate volume and the percentage of total ethanol content of palm sap were measured.
5. Bioethanol testing

Testing of bioethanol as fuel is carried out on a 4-stroke engine. The first step is to heat the motorbike engine before use by starting the engine using premium fuel. The fuel tank hose on the motor is disconnected and connected to the ethanol fuel hose that has been prepared. After that, remove the carburetor exhaust cover bolt to remove the remaining premium fuel stored in the carburetor.
6. Data analysis

The data obtained were analyzed using the regression method. The relationship between fermentation treatment and ethanol content can be seen from the resulting coefficient of determination (R^2). If the R^2 value approaches the number 1, it means that there is a close relationship.

3. Results and discussion

3.1. Bioethanol content

Calculation of ethanol content from fermentation and distillation of palm sap was carried out by the specific gravity method. The density of the sample was converted to the percentage of ethanol content using a Conversion Table. From the calculation results, the highest ethanol content was 45%, while the lowest was 41.67%. On the third day of fermentation, the ethanol content was lower than on the sixth day. This is thought to be due to the excessive volume of starter used, while the little fermentation time. This result is in line with the report of Fahrizal et al. [3] that too little enzyme concentration can cause slow fermentation time, whereas if the enzyme concentration is too high it can cause more ethanol to be converted. Furthermore, Tan et al. [6] reported that the higher the yeast concentration used, the higher the ethanol content was produced.

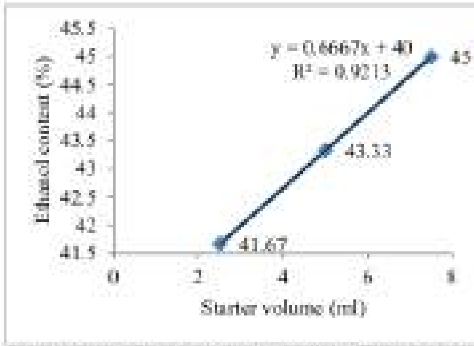

Figure 1. Relation of starter volume, the addition of coconut shell charcoal, and whiting to ethanol content.

The results of the regression analysis showed that the coefficient of determination (R^2) was 0.9213 (Figure 1). These results indicate that the starter volume has a significant effect on ethanol content. The higher the starter volume, the higher the ethanol content produced.

The longer the fermentation time, the higher the ethanol content produced. However, after the optimum conditions are reached, the ethanol content obtained tends to decrease. This is due to the low availability of glucose in the substrate. Besides, there has been a further reaction from ethanol, so that the ethanol obtained decreases with increasing fermentation time. This further reaction is due to the oxidation of ethanol to acetic acid. The degradation rate of glucose to ethanol is smaller than the rate of oxidation of ethanol to acetic acid so that the resulting ethanol content decreases. The same study was reported by Deesuth et al. [13] that the optimal fermentation time to produce ethanol using yeast saccharomyces cerevisiae is 3 days.

Another factor that affects the percentage of ethanol content of a compound is specific gravity. From the results of measuring the ethanol content using the specific gravity method, it shows that when the density of the ethanol solution is getting smaller, the ethanol content in the solution is getting bigger. This is because ethanol has lower specific gravity than water so that the smaller the density of the solution means the more ethanol content. This is in line with research conducted by Ansar et al. [8] that the ethanol content was inversely related to the density of ethanol produced. This happens because the density of ethanol under standard conditions is 0.789 g/cm^3, while the specific gravity of water is 1 g/cm^3, so that the greater the density of ethanol produced means the more water content in the product.

3.2. Use of bioethanol in combustion engines

The results of using bioethanol in the combustion motor to determine the combustion process of mixing bioethanol and premium are shown in Table 1.

Table 1. The results of using bioethanol in the combustion motor

Concentration (%)		Rotation speed
Bioethanol	Premium	(rpm)
5	95	3746
10	90	2779
15	85	1673

Table 1 shows that the highest rotation speed is in the ratio of bioethanol and premium concentrations of 5: 95. While the lowest rotation speeds, value is in mixing 15: 85 ethanol content. This shows that the higher the premium concentration, the higher the engine speed, which means combustion, occurs perfectly. This data is in line with the opinion of Yudistirani et al. [19] that the optimal mixture between premium and bioethanol can produce complete combustion which has an impact on increasing the rotation speed of the motor.

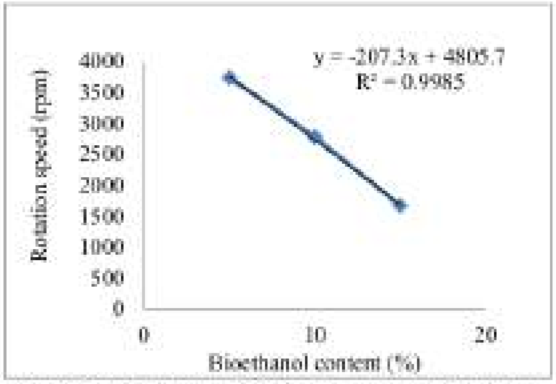

Figure 2. The relationship between bioethanol content and engine rotation speed

The results of the regression analysis between bioethanol content and engine rotation speed obtained the coefficient of determination (R^2) of 0.9985 (Table 2). This shows a close relationship between bioethanol levels and engine rotation speed. The higher the bioethanol content, the lower the motor rotation speed. This is presumably because the low octane number in bioethanol also affects the motor rotation speed. The same thing was revealed by Susila [20] that the optimal mixture of premium and ethanol will result in perfect combustion which has an impact on increasing the motor rotation speed.

4. Conclusion

The results of palm sap fermentation obtained the highest ethanol content of 45%, while the lowest was 41.67%. After the multilevel distillation process was carried out, the ethanol content was obtained up to 93%. This level of ethanol cannot be used in a 4-stroke motorbike engine properly because the motor rotation is unstable. The highest motor rotation speed is found in mixing 5% ethanol content and 95% premium. Meanwhile, the lowest rotation speed is found in mixing 15% ethanol content and 85% premium.

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