PRODUCTION AND CHARACTERIZATION OF BIOETHANOL FROM FERMENTATION, DISTILLATION, AND DEHYDRATION OF MANIHOT ESCULENTA CASSAVA

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Abstract

The average amount of fuel oil consumed in Indonesia increases by 6% annually but reserves and output decline by 10% annually. By 2025 and 2050, the government wants renewable energy to account for at least 23% and 31% of total energy consumption, respectively. A renewable energy source that can be created through fermentation, distillation, and dehydration is ethanol (C_2H_5OH). This procedure shows how important it is for people to learn how to find alternative energy sources. An essential component in the creation of ethanol is cassava, namely Manihot esculenta. This study aims to examine the process of creating bioethanol and to ascertain its ethanol content, density, pH, yield, and octane rating when blended with petroleum-based fuel. It also examines the yield and density of the bioethanol produced by the method. The experimental approach is used. The method of data analysis used in this study is descriptive research, which entails summarizing or explaining the collected data in its whole without the goal of generalizing or conclusions. According to the ethanol test results, there was 89.31% of ethanol present, 0.7705 g/mL of density, and a pH of 7.624. The yield from fermentation is 75.74%, the yield from distillation is 4.96%, and the yield of bioethanol per kilogram is 0.0103 L/kg.

Keywords: *Bioethanol, Fermentation, Distillation, Dehydration, Manihot esculenta*

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1. Introduction

The increasing human need for cars for transportation has accelerated the development of technology.Indonesians are driving more because their standards of living are rising[1], [2]. The Otto engine is one of the technological advancements in the realm of transportation. The Otto engine/gasoline engine is a type of internal combustion engine that is powered by spark plugs and runs on gasoline. Most internal combustion engines use a four-stroke cycle, with both spark and compression ignition combustion. A four-stroke engine is an internal combustion engine that has four work steps: suction, compression, effort, and exhaust [3].Vehicles with fuel injection have an electronic system that is centralized through the engine control unit.[4], [5]

The type of fuel needed to provide optimal engine performance, including torque and power, is inextricably linked to motorcycle use[6]. The combustion process would be impossible without fuel. Organic fuels are made up of carbon (C), hydrogen (H), nitrogen (N), oxygen (O), sulfur (S), and other components. The fuel is typically composed of hydrogen and carbon, denoted by the formula CnHm [7]. The octane number shows the quality of the fuel. In Indonesia, the octane number of gasoline is [8]:

Table .1 Octane Value of Indonesian Gasoline

Fuel Type	RON
Premium	88
Pertalite	90
Pertamax	92
Pertamax Plus	95
Pertamax Turbo	98

The need for renewable energy in Indonesia is growing, as is the usage of long-renewable fossil fuels, which is depleting these resources year after year. On the other hand, Indonesia's energy demand, particularly for gasoline, continues to rise year after year. The average consumption rate rises by 6% each year, but fuel reserves and output fall by 10% [9]. Many vehicles continue to run on fossil fuels that are difficult to replace. While difficult-to-renew fossil fuels will ultimately run out, it will take a long time to convert them back into fuel. As a result, to meet the needs of a wide range of vehicle fuels, an energy/fuel that is easily renewable and swiftly converted back into fuel is required [10].

The government intends to reduce gasoline consumption by 20% by 2025, with the remaining 80% replaced by other energy sources, notably renewable energy [11]. Furthermore, the government intends for new and renewable energy to play at least a 23% role by 2025, and at least 31% by 2050 [12]. Biofuel, a renewable alternative fuel, is one type of renewable energy. Through fermentation, distillation, and dehydration, ethanol (ethyl alcohol) (C_2H_5OH) can be produced as a biofuel. The qualities of ethanol biofuel are nearly identical to those of gasoline. As a result, it is appropriate for engines that use spark plugs to assist combustion [13]. This demonstrates the importance of people being able to discover alternate energy sources. Referring to the Standards and Quality (Specifications) of Bioethanol-Type Biofuels Marketed Domestically, namely 99.5% ethanol content, density 0.7936 - 0.7961, and pH 6.5 - 9.0 [14].

Ethanol as a fuel offers promising prospects. Ethanol is renewable since it may be produced from basic plant materials [15]. Cassava is a basic material for generating ethanol because it is easily available, easy to farm, has economic worth, is marketable and marketable, and includes a high carbohydrate content. Cassava production in Indonesia is plentiful, reaching up to 21 million tonnes [16]. One species of cassava is handled, with trees averaging 4-5 cm in diameter and producing no more than 10 kilogram per tree. Because this cassava provides a lot of starch, the community uses it a lot to prepare food. Cassava has a carbohydrate content of 63.6 grams [17]. Fermentation, distillation, and dehydration can all be utilized as renewable fuels if the carbohydrate content is high enough. Cassava's use in the community, which is still limited to food, only adds to its low selling value.

The following is a simple procedure for

converting cassava into ethanol:

1. Hydrolysis

Using the enzyme Alpha Amylase and a heating method (cooking), hydrolysis transforms carbs into simple sugars [18]. Peel fresh cassava, clean it with water, grate the cassava, and boil it in a 4:1 (4 liters of water to 1 kilogram of cassava) ratio while stirring continually until it thickens at 100ºC [19]. The liquid is heated at 80-90ºC, then cooled to 55ºC to continue the saccharification process after adding 3 ml of Alpha-Amylase enzyme and stirred until smooth. Add 3 mL of Glucose Amylase enzyme to the saccharification process and heat for 30 minutes at 50-60ºC [20]. Enzymatic hydrolysis has several advantages over acid hydrolysis, including minimal sugar degradation from hydrolysis, softer process conditions (low temperature, neutral pH), possibly high yields, and reduced maintenance costs due to the absence of corrosive components [21]. The acid-based saccharification process is non-specific and generates byproducts other than sugar, such as acetic acid [22].

2. Fermentation

Fermentation is defined as any aerobic or anaerobic microbial activity that causes a specified chemical change on an organic substrate [15]. At the same time, alcoholic fermentation can be viewed as a change in sugar molecules (substrates) by bacteria that results in the production of alcohol and CO_2 gas.

At this point, the starch solution transforms into a simple sugar solution with 5-12% levels. Adding Saccharomyces cerevisiae/yeast bacteria up to 10% of the total starch slurry and allowing to stand anaerobically (without air) in a closed container (fermenter) at 30-40ºC [19]. Even modest amounts of nutrients are required for the fermentation process. NPK 16.16.16 fertilizer (16% Nitrogen, 16% Phosphorus, 16 Potassium) is a nutrient component that can be added to this method. Because the supply of nutrients for bacterial growth is becoming increasingly sufficient, using 20 grams of NPK fertilizer per one kg of starch slurry yields the highest ethanol content [23].

The amount of bioethanol produced is affected by the fermentation period. The maximum ethanol level was produced after 168 hours. Because the Saccharomyces cerevisiae bacteria are in the exponential phase (the phase in which the most extensive ethanol product is formed) now. The ethanol content produced decreased during the 192-hour fermentation time because the Saccharomyces cerevisiae bacteria entered the death phase, so the number of microbes grew slower and there was no increase in the number of microbes that converted the substrate into ethanol, so the ethanol formed tended to fall [24]. Because the anaerobic process is not flawless, there is an aerobic process that allows the growth of Acetobacter Aceti, which can convert alcohol into acetate, which has a sour flavor. The following is the reaction:

$$C_2H_5OH_{(l)} + O_{2(g)} \longrightarrow CH_3COOH_{(1)} \text{ (acetic acid)} + H_2O_{(l)}$$

3. Distillation

Distillation is a technique that uses evaporation or re-condensation to separate a combination of two or more liquids into fractions depending on boiling point differences. At 78ºC (the boiling point of alcohol), ethanol will evaporate first, followed by water with a boiling point of 95ºC. The distillation vapor is delivered to the condenser, where it is condensed into liquid ethanol. To generate distillation liquid, the fermented liquid is placed in a boiling flask and heated to 80ºC [25].

4. dehydration

The distillation products cannot be dissolved in fuel. For gasoline, an ethanol percentage of 99.5 - 99.8% or dry ethanol is necessary. When purifying 95% ethanol, it will go through a dehydration process (absorbent distillation) that may involve the use of zeolite/limestone. Using zeolite stones by 90% of the total distilled liquid, certain dehydration process trials achieved the highest ethanol percentage of 99.73% (which satisfied full-grade bioethanol standards) [25]. The higher the ethanol level, the greater the capacity of the zeolite adsorbent to absorb water [26]. For about an hour, the technique is precipitated in distilled ethanol liquid. The ethanol is next filtered and dehydrated to generate pure ethanol with a purity of 99.5 - 99.8%.

2. Methods

The experimental approach was used, and this method is used when the researcher wants to discover the effect of cause and effect [27]–[30]. Meanwhile, the data analysis technique employed in this study is descriptive research. Descriptive statistical data analysis is statistics used to analyze data by describing or describing the data that has been acquired as it is without the intention of drawing generalizable conclusions or generalization [31]–[35].

Manufacturing Process and Bioethanol Characteristic Testing

The following is the technique for producing bioethanol from cassava and assessing its properties:

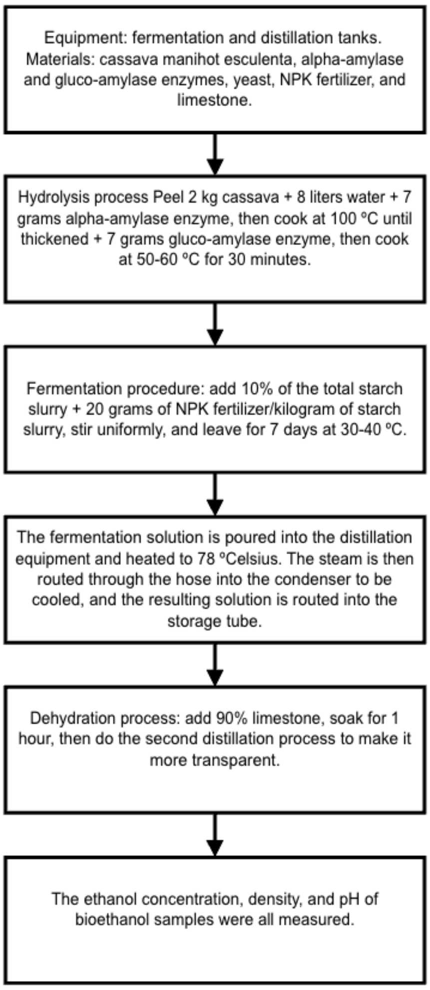

Figure 1. Production Process of Bioethanol

Based on the testing results and the characteristics of bioethanol, obtained data is then compared with the Indonesian National Standard of bioethanol. The following is a comparison of bioethanol test results with Indonesian National Standard (SNI) bioethanol:

Table 2. Comparison of SNI Bioethanol with Bioethanol Test Results

Parameter	SNI	**Bioethanol Testing**
Bioetanol Result (Liter)	-	0,515
Ethanol Ethanol level (%)	99,5	89,31
Density (15^{o}C) g/mL	0,7936 – 0,7961	0,7705
pH	6,5 – 9,0	7,624

Table 2 contains detailed information regarding the properties, including bioethanol yield (litres), ethanol content (%), density (15 ºC) g/mL, and pH. The results of the tests show that the bioethanol yield is 0.515 litres, the ethanol content is 89.31%, the density is 0.7705 g/mL, and the pH of the bioethanol solution is 7.624. The ethanol concentration and density test findings indicate that the bioethanol sample does not meet the SNI quality parameters that must be met during testing. The samples' ethanol concentration and density are below the specified standard standards. As a result, the manufacturing process must be analyzed and enhanced to satisfy the established criteria. The pH test findings of the bioethanol solution, on the other hand, reveal that the bioethanol sample meets the preset SNI quality standards. The pH of the bioethanol solution derived from the sample is within the stipulated quality standard range. Table 2 can be used to determine whether bioethanol samples meet the SNI quality standards that must be considered during analysis. However, the manufacturing method should be assessed and improved so that the bioethanol samples meet the established standards for other critical parameters.

The following data is obtained based on the results of the calculated yield of the bioethanol manufacturing process:

Table 3. Bioethanol Yields Calculation

Calculation Type	Value
Yield of fermentation (%)	75,74
The distillation yield (%)	4,96
Bioethanol yield per kilo (L/kg)	0,0103

Table 3 displays the bioethanol yield calculation data and can be used to assess the efficiency of the bioethanol manufacturing process. Only 75.74% of the raw materials utilized in the fermentation process were successfully transformed into bioethanol, according to the fermentation yield calculation. Furthermore, the distillation yield only reached 4.96%, indicating that the majority of the bioethanol is still in the still and that the amount of bioethanol extracted in the distillation is rather little. This might be considered while designing a more efficient bioethanol production process. Calculations on bioethanol product per kg, on the other hand, suggest that bioethanol production per kilogram of feedstock used is 0.0103 L/kg. Bioethanol production can be raised in this situation by increasing the efficiency of the fermentation and distillation processes based on the feedstock necessary to create the desired amount of bioethanol.

From 50 kilograms of raw materials, 0.51 liter of bioethanol was produced. Since water and enzymes are used in the hydrolysis process, fermentation produces more water than ethanol does. The rapid rise and fall in temperature caused by manual use of the stove can affect the distillation process, changing the temperature conditions. The size of the fire must be reduced when the distillation tank's temperature rises above 78°C. so that when the distillation temperature gets close to 100°C, ethanol evaporates during the process of boiling water. This is consistent with research showing that unstable temperatures can result in product loss, affecting the yield and quality of bioethanol distillation. The amount of product produced can be decreased by unwanted products evaporating because of frequent temperature changes [14]. When bioethanol is produced by burning, the blue flame that results from combustion denotes a high concentration of ethanol in the liquid [24].

Another fuel sold in the nation is bioethanol. The ethanol content standard is 99.5% [9]. According to test results, bioethanol is 89.31%. Bioethanol still contains a sizable amount of water. This study discovered that the highest bioethanol content ever, at 74%, was produced at a higher ethanol content [19]. The water content is decreased by the addition of the limestone-based dehydration process. The ethanol is dried in such a way that the higher the mass of adsorbent used, the greater its capacity to absorb water, resulting in a higher ethanol content [26].

Density for bioethanol is typically between 0.7936 and 0.7961 g/mL [14]. The test results reveal that bioethanol has a density of 0.7705 g/mL. The amount of bioethanol produced falls short of the minimum required amount, though density test results show only a slight discrepancy. Therefore, it has little impact on engine performance. The amount of heat energy produced and engine output decrease with increasing ethanol content in the mixture. The quality of the fuel mixture, including engine performance, may be impacted if the specific gravity of bioethanol and pertalite is below the established standard.

The pH measurement result of bioethanol from Manihot Esculenta cassava is 7.624, which meets the requirements of biofuel standards and quality (specifications) for bioethanol. This is because during the hydrolysis process using enzymatic, neutral pH is one of the advantages of this enzymatic hydrolysis. The advantages of enzymatic hydrolysis over acid are no degradation of hydrolyzed sugars, milder process conditions (low temperature, neutral pH), high yield potential, and low maintenance costs as no corrosive substances are included [21]. The saccharification process with acid is non-specific and produces another by-product besides sugar, acetic acid [22].

The calculation of fermentation yield is 75.74% [19], obtained by distilling starch slurry from 50 kg of raw materials. This distillation yield shows the percentage ratio between the distillation results and the fermentation solution obtained. The calculation of distillation yield was obtained at 4.96% [19]. At the same time, the calculation of bioethanol yield per kilogram of raw material is 0.0103 liters/kg [19]. So, every one kg of Manihot esculenta cassava produces 0.0103 liters of bioethanol.

Conclusion

Bioethanol characteristics must be improved to meet the standards of other essential parameters. Although the pH of the bioethanol solution meets SNI quality standards, the results of the ethanol content test and density test show that the sample does not meet the SNI test. Overall bioethanol production efficiency must also be improved by improving the fermentation and distillation process to increase the amount of bioethanol produced proportionately to the number of raw materials used. However, the mixture of pertalite and bioethanol fuel shows the potential of using bioethanol as an environmentally friendly and efficient alternative fuel because it can increase the octane number and engine performance.

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