Effect of fermentation duration on rice straw (*Oryza Sativa L*) in bioethanol quality

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Abstract. Rice straw (*Oryza sativa* L.) can be used to produce bioethanol. Bioethanol is a liquid alternative fuel that has the potential to serve as a substitute for, and potentially even replace, fossil fuels. Hence, considering the substantial amount of agricultural waste generated and its underutilization, it is feasible to transform agricultural waste into a liquid fuel known as bioethanol. Rice straw is a type of agricultural waste that can be transformed into bioethanol, a form of liquid fuel. The rice straw conversion process involves the utilization of hydrolysis, fermentation, and distillation techniques for the production of liquid fuel. This study employed an experimental approach, utilizing yeast quantities of 20% and 30% as the fermentation substrate. Additionally, variations in fermentation duration were investigated, specifically 7, 8, 9, and 10 days. This research aims to assess the quality of liquid solid fuel (Bioethanol) by measuring its heating value and flash point. Rice straw is used as the raw material for this investigation. Bioethanol, a liquid solid fuel, can serve as a viable substitute for fossil fuels in several applications. The time of fermentation has a direct correlation with the production of bioethanol. The maximum bioethanol yield obtained in this study was 34.4%, which was achieved after 9 days of fermentation. This substance has a flashing point of 21°C. The density of the fermentation at 9 days is 0.79 gr/ml, which is the lowest recorded value.
Keyword: bioethanol, density, duration, fermentation, flashpoint, rice straw,

1 Introduction

Indonesia is actively working to enhance its biofuel production to meet the growing demand for fuel and reduce dependency on imported oil. The Indonesian government has submitted its plan for committed to achieving net-zero emissions by 2060. Since 2023, Indonesia's biodiesel production reached approximately 13.15 million kilo-litres, a significant increase from previous years. This boost in production is largely attributed to the government's policy of increasing the biodiesel blending mandate to B35, which includes 35% palm oil-based biofuel mixed with conventional diesel [1]. The country's biofuel initiatives are aimed at addressing several key challenges, including decreasing domestic oil production and the need for sustainable energy solutions. The use of biodiesel is expected to reduce greenhouse gas emissions by around 34.9 million tonnes of CO2 equivalent, contributing to environmental sustainability efforts [2]. Moreover, the increased production of biodiesel primarily uses palm oil, with about 93% of the output being consumed domestically and the remainder exported. This shift has significant economic implications, such as reducing the trade balance deficit, creating jobs, and increasing the value added to crude palm oil [3].

Alternative fuels are waste products that are converted to replace petroleum fuels. These fuels can be derived from various sources, including agricultural waste, which is often left unused and unutilized[4]. Agricultural waste is abundant throughout Indonesia, as the country is predominantly agrarian, with a large portion of the population engaged in farming activities[5]. Indonesia's vast agricultural sector produces a significant amount of waste, including rice straw, which is one of the primary types of agricultural waste. Instead of allowing this waste to accumulate and potentially cause environmental issues, it can be transformed into a valuable resource: bioethanol [6-7].

Rice straw, an abundant agricultural byproduct. Despite that on dry condition it have 34.2% of cellulose, followed by 24,5% of hemicellulose and lignin is 23.4% on dried condition [8]. Density of rice straw is 50 to 120 kg/m^3, it shrinks to 13 to 18 kg/m^3on dry condition [9]. Given its composition, rice straw presents a promising feedstock for the production of bioethanol, a renewable and sustainable biofuel. The high cellulose and hemicellulose content can be hydrolyzed into fermentable sugars, which are essential for bioethanol production [10].

This research observed sugarcane bagasse, switchgrass, cheery wood, and corn cobs for bioethanol. They have more than 40 percent of cellulose content. The application of pretreatments such as extrusion, steam explosion combined with mild acids, mild thermo-alkaline, green liquor, and surfactants combined

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with a steam explosion increased sugar conversion and bioethanol production [11].

The research observed about possibility bioethanol for public transport fuel in Netherland. It results lignocellulosic bioethanol production can replace about 31% fossil fuel [12].

2 Methods

This study employed an experimental methodology to conduct the testing procedure. The research test site was evaluated at the laboratory of automation systems and robotics over a period of 6 months. Below is a schematic diagram of the research apparatus for bioethanol distillation, specifically designed for the utilisation of rice straw biomass.

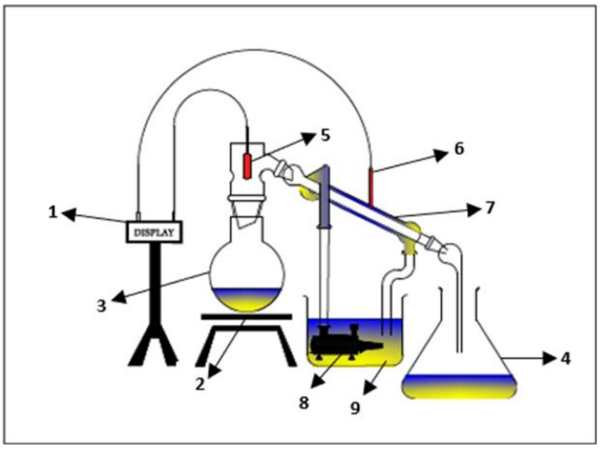

Fig. 1. Illustration of distillation plant.

Image Description:
1. Temperature display
2. Heater
3. Distillation flask
4. Collection flask
5. Thermometer 1
6. Thermometer 2
7. Condenser
8. Water pump
9. Cooling water reservoir

2.1 Receptiveness on production of bioethanol

Preparation and process of bioethanol manufacturing involves the necessary steps and procedures to produce bioethanol. Rice straw waste serves as the primary source of raw material for bioethanol the production process. The raw material undergoes various procedures, which include:

a. Cleansing and rinsing the rice straw with water.
b. Drying under sun for 6 hours the rinsed husk.
c. Pulverising the rice straw in a blender and then straining it to obtain flour.
d. First, measure 200 grammes of rice straw flour. Next, dissolve the flour in 800 mL of distilled water. Stir the mixture for 1 hour at a temperature between 90 and 100°C.
e. The hydrolysis products are filtered using filter paper and then rinsed with distilled water until the volume of the filtrate reaches 250 ml.
f. The soluble carbohydrates in this filtrate are discarded.
g. The hydrolysis results were placed in a container and 15 grammes of yeast were added.
h. Storage fermentation is conducted for a duration of 7, 8, and 9 days.
i. Subsequently, the distillation procedure was conducted at a temperature of 90 °C, with data samples collected at 30-minute intervals.

3 Result and discussion

The experiment involved measuring 15 grammes of rice straw powder and conducting sieving tests using 4 different treatments. The initial powder was mixed with a solution of hydrochloric acid (15%-20%), the second powder was mixed with a solution of hydrochloric acid (7%-10%), the third powder was mixed with a solution of sulfuric acid (15%-20%), and the fourth powder was mixed with a solution of sulfuric acid (7%-10%), with each solution having a volume of 180 ml. Next, proceed to heat each mixture at a temperature of 100 degrees Celsius for a duration of 2 hours. The alteration in hue following the application of the acidic solution is observable in Table 1.

Table 1. Alteration in the colour of a solution following hydrolysis.

No	mm	Final colour
1	HCl (15%-20%)	Dark Brown
2	HCl (7%-10%)	Brown Hue
3	H_2SO_4 (15%-20%)	Dark Brown
4	H_2SO_4 (7%-10%)	Brown Hue

Table 1 demonstrates that solutions of HCl and H_2SO_4 with concentrations ranging from 15% to 20% result in the rice straw's colour turning into a dark brown shade. This demonstrates that hemicellulose or cellulose undergoes complete degradation, resulting in the production of glucose. Nevertheless, elevated amounts result in further decomposition of hemicellulose into carbon. Cellulose exhibits incomplete degradation in solutions of HCl and H_2SO_4 (7-10%), as seen by a faint brown hue.

3.1 Result of bioethanol strature

The collection of bioethanol test data commences by preparing hydrolyzed raw materials, which are subsequently placed in a heating container for the distillation procedure. To ensure the accuracy of the research data, the fermentation results from each day were isolated from the other containers. Subsequently, a heating procedure was conducted for the distillation process, with a temperature range of 78-80oC. The subsequent data presents the values of bioethanol quality metrics obtained from rice straw waste.

3.1.1 Water content

The moisture content of bioethanol can be analysed by subtracting the initial weight of the fermentation product from the final weight of the distillation product. The result of this analysis can be explained in the graph of the relationship between moisture content and fermentation time.

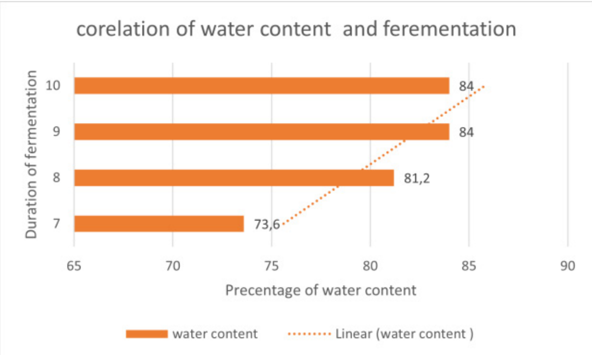

Fig. 2. Graphic corelation between water content and fermentation duration.

Figure 2 reveal the moisture content of bioethanol can be analyzed by subtracting the initial weight of the fermentation product from the final weight of the distillation product. This process involves first measuring the weight of the fermentation mixture, which includes the bioethanol, water, and any residual solids. After distillation, the weight of the remaining product, primarily composed of bioethanol and a reduced amount of water, is measured again. The difference in these weights gives a clear indication of the water content in the bioethanol. The results of this analysis can be explained in the graph of the relationship between water content and fermentation time. This graph typically shows how the water content in bioethanol changes over different fermentation periods, highlighting trends such as the increase in water content with longer fermentation times. By analyzing this relationship, researchers and producers can better understand the efficiency of the fermentation and distillation processes, and make necessary adjustments to optimize the production of high-quality bioethanol with minimal moisture content.

It can be explained in the figure above that the value of water content increases as the fermentation time increases, the results obtained have not yet entered the bioethanol quality requirements, which is a maximum water content of 2%. The highest moisture content was 84% with 9 days and 10 days of fermentation. The lowest value for water content was 73.6%. This proves that the longer the fermentation time, the higher the water content during distillation. A large value of water content gives a small combustion value. Specifically, in bioethanol made from oil palm crude, the moisture content can range from 70% to 85% after fermentation[13]. In comparison, bioethanol made from oil palm fruit tends to have a lower moisture content, typically ranging from 60% to 75% after fermentation[14]. the moisture content of bioethanol from sugarcane bagasse usually ranges from 60% to 80%[15]. This indicates that while both feedstocks require efficient dehydration processes to meet bioethanol quality standards, bioethanol from oil palm fruit may require slightly less intensive dehydration than that from oil palm crude[16].

3.1.2 Density

Density value is a crucial parameter for assessing one of the key physical properties of bioethanol fuel. It provides valuable information about the purity and composition of the bioethanol, which is essential for ensuring its quality and performance as a fuel. To perform density analysis, a 10 ml sample of bioethanol is taken and its mass is measured using a digital scale with high precision. The density is then calculated by dividing the mass of the sample by its volume, resulting in a grams per milliliter (g/ml) unit. The accuracy of this measurement is vital, as density can be influenced by the presence of impurities, water content, and the concentration of ethanol. By analyzing the density values over different fermentation periods, researchers can gain insights into the progress of the fermentation process, the efficiency of ethanol production, and the potential need for further purification. The results of this density analysis, which are plotted on a graph, illustrate how the density of bioethanol changes with varying fermentation durations. This data helps in understanding the relationship between fermentation time and ethanol concentration, and in determining the optimal conditions for producing high-quality bioethanol fuel.

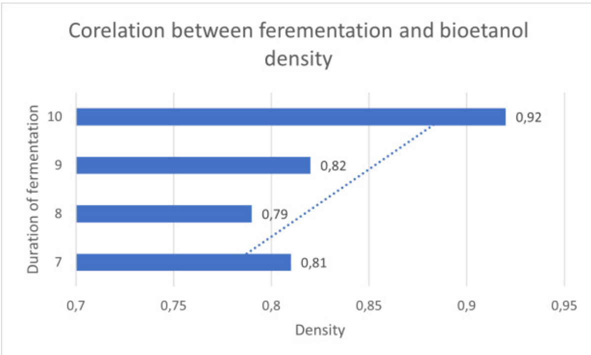

Fig. 3. Graphic corelation between density and fermentation duration.

Figure 3 display about relationship between density value and fermentation duration, it can be seen that the highest value is in the 7-day fermentation period with a density value of 0.92 g/ml³. The lowest density value of 0.79 g/ml was in the 9-day fermentation period. The density value tends to rise back to 0.81 g/ml³ at 10 days of fermentation, proving that the decomposing bacteria have finished breaking down glucose into bioethanol. The lower the density value of bioethanol, the better it is because the ability of the liquid to evaporate can be influenced by the lower density value, as glucose contained in the biomass is converted into bioethanol. Specifically, bioethanol from oil palm typically has a density ranging from 0.79 to 0.82 g/ml³ at 20°C [17], while bioethanol from sugarcane bagasse generally ranges from 0.79 to 0.81 g/ml³ at 20°C. This suggests that the observed density values in the experiment fall within the typical range for bioethanol produced from these feedstocks[18].

3.1.3 Bioethanol content

The bioethanol content parameter has a very important function for bioethanol quality testing, namely testing the alcohol content of bioethanol. This test uses an alcohol meter to measure the percentage of alcohol contained in the purified bioethanol sample. The following graph shows the relationship between bioethanol content and fermentation time.

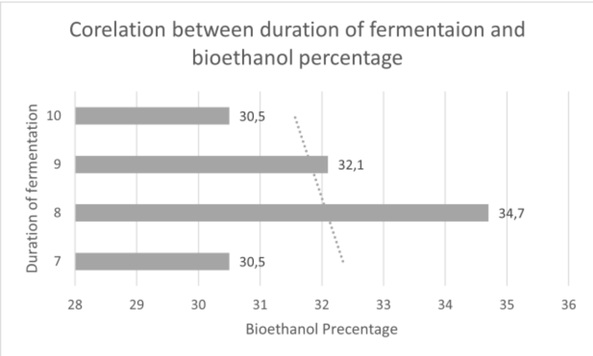

Fig. 4. Graphic corelation between bioethanol percentage and duration of fermentation.

Based on figure 4 the value of bioethanol content from rice straw has the largest value of 34.7% with a fermentation duration of 9 days, then decreased to 33.0% at a fermentation duration of 10 days. This decrease is due to the fermentation process on day 10 reducing the quality of glucose conversion into alcohol. The lowest bioethanol content was 30.5% with 7 days of fermentation. The higher the bioethanol content, the better the quality of the bioethanol, which is influenced by more effective microbial activators during the fermentation period converting glucose into bioethanol. The bioethanol content is also affected by the heating temperature in the distillation process, with the recommended temperature being 78-80°C. For comparison, bioethanol production from different feedstocks shows variable ethanol content. Corn typically produces about 40-45% ethanol based on the dry weight of the corn[19], with yields of approximately 400-450 liters of ethanol per metric ton of corn. Wheat produces about 35-40% ethanol based on the dry weight of the wheat[20], with yields of approximately 350-400 liters of ethanol per metric ton of wheat[21]. These values highlight the efficiency of different feedstocks in bioethanol production and underscore the importance of optimizing fermentation and distillation processes to achieve high ethanol content.

3.1.4 Heating value

Calorific value is the heat energy produced by the combustion of fuel per unit mass of fuel. The calorific value indicator is an important part of the quality evaluation process of liquid fuels. The greater the calorific value of a fuel, the more heat energy it can release during combustion. This is significant because a higher calorific value facilitates the combustion process, leading to improved engine performance. In other words, fuels with higher calorific values have the potential to generate more energy when burned. The calorific value of a fuel is typically determined experimentally using a calorimetric bomb, which measures the heat released during combustion. The unit of calorific value is often expressed as kilojoules per kilogram (kJ/kg). It is important to note that the calorific value can vary depending on the composition and properties of the fuel. In the context of the provided information, the results of the calorific value analysis on rice straw are mentioned, but specific values are not provided. However, it is implied that the calorific value analysis is conducted to assess the energy content of rice straw as a potential fuel source. The following are the results of the calorific value analysis on rice straw.

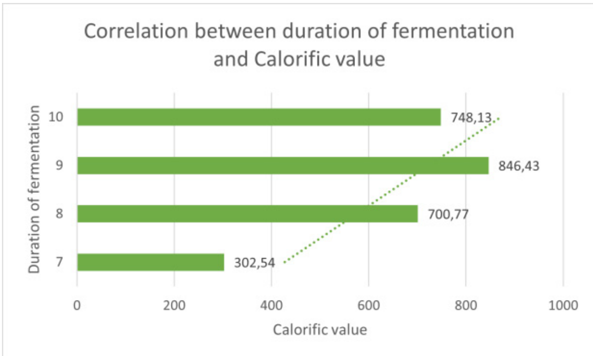

Fig. 5. Graph of calorific value relationship with fermentation duration.

The calorific value presented in the graph above can be seen that the highest calorific value is found in 9 days of fermentation with a value of 846.43 kcal/kg, and the lowest calorific value is 302.54 kcal/kg in 7 days of fermentation. The calorific value is directly proportional to the alcohol content of the bioethanol fuel, due to the fact that microbial activity in converting glucose into bioethanol increases with increasing fermentation time, but there is a decrease of 100kcal/kg at 10 days fermentation time. Microbial activity does not always continue to increase, but tends to decrease after the glucose breakdown process contained in bioethanol has been exhausted in the storage reactor. However, this value is still low when compared to bioethanol yields from corn, palm kernel heads, bagasse and wheat which are in the range of 6,200-7,200 kCal/kg.

3.1.5 Flash point

Another important indicator of the value of supporting characteristics in liquid fuels is the flash point value. Flash point in bioethanol fuels is a value to determine the ability of a liquid fuel to remain vaporised at low temperatures. This physical property is carried out with the aim of safety in the use of liquid fuels in industry, automotive and medical needs. Here are the results of the flash point test for bioethanol fuel from rice straw waste.

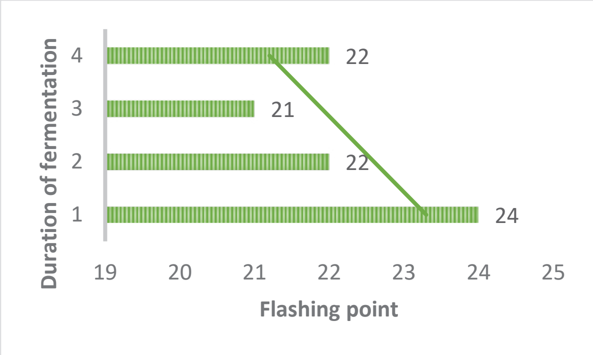

Fig. 6. Graph of relationship between flashing point with fermentation duration.

Figure 6 shown relationship between flash point and fermentation duration The graph of the relationship between flash point and fermentation duration above shows that the lowest flash point value is 21°C at a fermentation duration of 9 days, and the highest temperature value is 24°C at a fermentation duration of 7 days. The flash point value provides evidence that the content of bioethanol is volatile at low temperatures, which is influenced by the low density of bioethanol fuel, and the ability of bioethanol fuel to burn easily can be influenced by the water or H_2O content still contained in bioethanol. For context, the flash point of pure ethanol is approximately 13°C, and this value is consistent across various sources of bioethanol, including those made from wheat, corn, palm oil, and sugarcane bagasse. These values are indicative of ethanol's properties and reflect the general volatility of bioethanol. Variations in the flash point during the fermentation process are primarily influenced by the purity of the bioethanol and the presence of any residual water or impurities.

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