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Characteristics and Potential of Bioetanol Gel from Janeng Starch (*Dioscorea hispida*) Using Local Yeast

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ABSTRACT

A research on bioethanol gel from janeng starch has been conducted with the aim of evaluating the hydrolysis process using water and the use of Carboxymethyl cellulose (CMC) to increase the calorific value of bioethanol gel. The method used in this study is the isolation of janeng starch, hydrolysis using water then fermented in an incubator for 24 hours, 48 hours and 72 hours. After fermentation, bioethanol was distilled and added with 5% Carboxymethyl cellulose (CMC) to increase its calorific value. The results obtained in this study are: ignition time at a yeast concentration of 5% 24 hours, 48 hours did not ignite and ignited for 7.26 seconds at a fermentation time of 72 hours. Yeast concentration of 10% 24 hours 0 seconds, 48 hours 13.51 seconds and 72 hours 25.11 seconds. Yeast concentration of 15% 24 hours 0 seconds, 48 hours 29.37 seconds and 72 hours 33.52 seconds. Then tested using GC-MS obtained bioethanol content of 76.53%. The test results pH 7.0 and viscosity 0.907 J / g. The results of the bomb calorimeter test obtained 648.47J, 2757.13J and 3392.49J for gel bioethanol, while for liquid bioethanol without a mixture of Carboxymethyl cellulose (CMC) obtained 3049.98J. The general conclusion stated that the addition of Carboxymethyl cellulose (CMC) to bioethanol can increase the calorific value of bioethanol.

Keywords: Bioethanol; Janeng; Calorie; Starch; Gel; Carboxymethyl Cellulose; Fermentation; Isolation; Hydrolysis; Water.

1. Introduction

Continuous drilling for petroleum in Indonesia will cause its supply to dwindle day by day. Several alternative energy sources to replace petroleum are solar, hydro, geothermal and materials from plant fermentation. One of the popular materials from plant fermentation is bioethanol because it can replace petroleum in Indonesia [1]. In the last five years, there has been a significant focus on bioethanol research, with advances in system dynamics modeling for the bioethanol sector. Bioethanol, which comes from various biomass sources, is gaining attention as a renewable alternative to fossil fuels due to its clean and environmentally friendly nature. Bioethanol production involves processes such as pre-treatment, enzymatic hydrolysis, fermentation, and distillation, with challenges in biomass pretreatment affecting overall efficiency. In addition, literature analysis on alcohol fuel research has shown a growth pattern that fits the epidemic model, providing insight into the distribution of research articles in journals. Furthermore, the exploration of bioethanol as a biofuel with superior energy efficiency [2].

The bioethanol library includes key findings from various studies. These findings include measurements of excess molar volume and excess relative permittivity in binary mixtures of N,N-dimethylacetamide with different ethanols, measurements of dielectric relaxation in binary mixtures of 2-Methoxyethanol with Ethanol, indicating solute interactions and hindered dipole rotation, and calculations of excess molar volume, isentropic compressibility, and viscosity deviation of binary mixtures of 2-methylaniline with substituted ethanols, indicating the involvement of dipolar association, molecular size and shape differences, dipole interactions, and hydrogen bonding. These studies provide insights into the molecular interactions, structural aspects, and

thermodynamic properties of bioethanol systems, contributing to a deeper understanding of their behavior and properties [3].

Bioethanol is produced through biological processes from starch-containing materials. All plants containing starch have the potential to be used as raw materials for bioethanol production. However, all of these plants are staple foods, which are feared to disrupt the stability of food security. *Dioscorea hispida* is usually called poisonous gadung in Indonesian and in Acehnese it is called janeng, which is a potential source of starch in bioethanol production [4].

This plant grows wild, has a high starch content, is not a staple food and is easy to cultivate because it is free from pests and is very economical. Janeng has a high cyanide acid content and dioscorin which is very toxic to animals and humans. Cyanide acid poisoning above 50 mg/kg can cause death, making this plant not used as a food crop [5]. Its easy maintenance and supported by the fact that Indonesia is the second largest janeng producing country in the world after Nigeria. This makes janeng very potential to be cultivated and used as a basic material for making economical and environmentally friendly bioethanol. The use of janeng as the main raw material for making bioethanol is expected to provide added economic value for farmers who cultivate it.

The use of bioethanol has disadvantages because it is liquid and volatile. For example, a fire incident occurred during the distribution of bioethanol. For this reason, the author also offers a new innovation, namely the manufacture of bioethanol gel. Bioethanol in gel form has several advantages, namely it is safe in distribution, does not evaporate easily, does not spill easily and is easy to apply without the need for special compost. In addition to these advantages, bioethanol gel has a longer burning time than liquid bioethanol.

The hydrolysis process in bioethanol production generally uses acid. However, recent research has shown that bagasse can be hydrolyzed using only water. This research develops a more environmentally friendly water-based hydrolysis method. Another innovation in this study is the use of local yeast from Aceh as a substitute for the more expensive Saccharomyces cerevisiae, thus making the production process more economical. This research is expected to provide an innovative solution for energy self-sufficiency by utilizing the toxic gadung plant, which has long been considered a pest [6].

1.1. Study Objectives

1. To evaluate the potential of bioethanol gel from janeng starch.

2. To evaluate the hydrolysis process of bioethanol using simple solutions such as water.

3. To solve the problem of volatile and reactive ethanol by converting it into bioethanol gel that is easy to distribute and apply in the field.

4. Explain the process of making bioethanol gel from janeng starch.

5. Provide information that hydrolysis can be carried out using simple solutions such as water without the need for strong acids.

2. Materials and Methods

2.1. Tools and Materials

The materials needed for starch isolation are poisonous gadung tubers, distilled water. The tools needed for starch isolation are: knife, blender, oven, 100 mesh sieve, analytical balance, Buchner filter, measuring flask, beaker, fine porous cloth, filter paper, bucket, closed container and a set of vacuum tools. Meanwhile, the tools for hydrolysis are Erlenmeyer flask, magnetic stirrer, measuring cup, spatula, digital scale, hot plate, thermometer, pH meter, burette and beaker.

In the ethanol fermentation process, plastic containers, pycnometer, stirrer, magnetic stirrer and measuring cup are used. The manufacture of bioethanol gel uses bioethanol material from distillation, plastic molds, CMC, hot plate and spatula.

2.2. Research Procedures

2.2.1. Preparation Stages of Janeng Starch Isolation Standard

A total of 10 kg of Janeng tubers were peeled and cleaned. Next, the tubers were diced, cleaned and blended for 5 minutes, after adding distilled water with a ratio of 1:1 (w/v). The tuber pulp was squeezed using a fine-pored cloth. The resulting sediment was filtered using a Buchner filter with the help of a water vacuum and washed several times with distilled water. The resulting starch flour was stored at room temperature in a tightly closed container before being used to produce bioethanol gel.

2.2.2. Hydrolysis of Janeng Starch

A total of 100 grams of starch was added with distilled water with a starch: water ratio of 1:3 (B/V). After the addition of the reagent was complete, the beaker was covered using aluminum foil. Then the starch was hydrolyzed at a temperature of 85°C for 250 minutes.

2.2.3. Bioethanol Fermentation

The hydrolysis results were added with yeast at a concentration of 9 percent (w/w) for 24 hours, 48 hours and 72 hours under anaerobic conditions. After that, it was filtered and distilled to obtain high ethanol content.

2.2.4. Making Bioethanol Gel Starch Janeng

Bioethanol is mixed with 4.5 percent CMC, left until the bioethanol and CMC are mixed.

2.3. Analysis

2.3.1. Flame Duration Analysis

Weigh 5 grams of bioethanol gel, then put it in a cup. Prepare a stopwatch. Next it is burned. Turn off the stopwatch when the bioethanol starts to burn.

2.3.2. Heat Analysis

Heat measurement is carried out using a bomb calorimeter. One gram of test sample is weighed, then placed in a silica cup, then inserted into the bomb calorimeter. Combustion begins when the water temperature is constant. Measurements are carried out until the temperature reaches its maximum.

3. Results and Discussion

3.1. Flame Duration with Varying Yeast Concentration in Bioethanol

Fermentation is a key process in bioethanol production, especially when the raw material contains high starch or sugar content. This process involves microorganisms, such as yeast (Saccharomyces cerevisiae), which convert sugar compounds into alcohol and carbon dioxide through anaerobic metabolic reactions. Yeast's role in this process is not only as a biological catalyst but also as a controller of the dynamics and efficiency of the fermentation process. In the context of bioethanol production from starchy materials, such as yam, cassava, or corn, optimal fermentation is crucial for achieving high ethanol content, which in turn affects the quality of bioethanol as an alternative fuel.

Bioethanol fermentation was carried out using local yeast (Saccharomyces cerevisiae). The hydrolyzed raw materials were then fermented with varying yeast concentrations of 5%, 10%, and 15% (w/w). Fermentation times varied from 24, 48, and 72 hours. Fermentation took place at room temperature (±28–30°C) under anaerobic conditions in a closed container. No additional stirring was applied during the fermentation process. After fermentation was complete, the resulting solution was filtered and used to produce bioethanol gel and to test its physical characteristics and calorific value.

Four sample variations were used in this study: P1, P2, P3, and P4. Sample P1 was a bioethanol gel produced through fermentation with a 5% yeast concentration for 72 hours. Sample P2 was fermented using a 10% yeast concentration for the same fermentation time, 72 hours. Sample P3 was fermented using a 15% yeast concentration for 72 hours and served as the primary sample with the best performance. Meanwhile, sample P4 had the same fermentation conditions as P3, namely a 15% yeast concentration and 72 hours of fermentation time, but without the addition of the thickener carboxymethyl cellulose (CMC).

Table 1. Effect of yeast concentration and fermentation time on the flame duration of Bioethanol Gel (seconds)

Yeast concentration	Fermentation time	Long ignition time
5 %	24 hours	0 second
	48 hours	0 second
	72 hours	7.26 second
10 %	24 hours	0 second
	48 hours	13.51 second
	72 hours	25.11 second
15 %	24 hours	0 second
	48 hours	29.37 second
	72 hours	33.52 second

One important parameter that significantly influences the fermentation process is yeast concentration. The higher the yeast concentration used, the more enzymes are available to catalyze the conversion of sugar to ethanol. This is because yeast produces enzymes such as invertase and maltase, which accelerate the breakdown of complex sugars into glucose and then convert it into ethanol. However, increasing yeast concentration must also be balanced with the availability of substrates (sugars) and other supporting nutrients. If substrate is limited, excessively increasing yeast concentration can actually lead to internal competition, reduce conversion efficiency, or stress yeast cells [7].

Experimental data shows a positive correlation between increasing yeast concentration and the ignition duration of the bioethanol produced. At a yeast concentration of 5%, the ignition duration was 0 seconds at 24 and 48 hours, while after 72 hours of fermentation, it only reached 7.26 seconds. However, increasing yeast concentrations to 10% and 15% significantly impacted the ignition duration of the bioethanol. At a concentration of 10%, the ignition duration increased. At a concentration of 15%, the ignition duration reached 33.52 seconds, the maximum value in the experiment. This indicates that the higher the yeast concentration, the higher the ethanol content produced during fermentation, as more sugars are successfully converted [8].

In addition to yeast concentration, fermentation time is also a crucial factor in influencing the final results of the fermentation process. The fermentation process requires time for the microorganisms to work optimally to convert sugars into ethanol. If the fermentation time is too short, sugar conversion will be incomplete, resulting in low ethanol production. Conversely, if fermentation is prolonged, yeast activity can be impaired due to the accumulation of ethanol, which is toxic to the microbes themselves, and nutrient limitations in the fermentation environment. In this study, a fermentation time of 72 hours was found to be the optimum time, providing the highest ethanol yield and best ignition performance, especially at high yeast concentrations [9].

The ignition duration of a bioethanol flame directly reflects the ethanol concentration in the fermentation solution. Bioethanol with a high ethanol content will have a higher combustion calorific value, resulting in a more stable and long-lasting flame. Therefore, the flame duration can be used as a practical indicator for assessing the quality of the bioethanol produced. In this context, increasing the ignition duration at higher yeast concentrations and optimal fermentation time demonstrates that the combination of these two factors plays a crucial role in optimizing the production of high-quality bioethanol [10].

These findings have significant practical value in the development of the bioethanol industry, particularly on a small- to medium-scale basis in areas with significant local biomass resource potential. Determining the optimal combination of yeast concentration and fermentation time not only improves production efficiency but also reduces operational costs. With higher-quality bioethanol, the fermentation product can be directly used as a blending fuel with gasoline without the need for a complex further purification process. This will be highly beneficial in the development of community-based renewable energy.

The increase in ignition time of bioethanol observed in the study with increasing yeast concentration and fermentation time is a phenomenon closely related to the biochemical processes of alcohol fermentation. Specifically, this can be explained through the basic principles of enzymatic kinetics theory, where the rate of a

chemical reaction is influenced by the amount of enzymes available in the system. In the context of bioethanol fermentation, yeasts such as Saccharomyces cerevisiae and other species (e.g., Candida sp., Pichia sp.) produce key enzymes, such as zymase, which catalyzes the conversion of glucose into glucose.

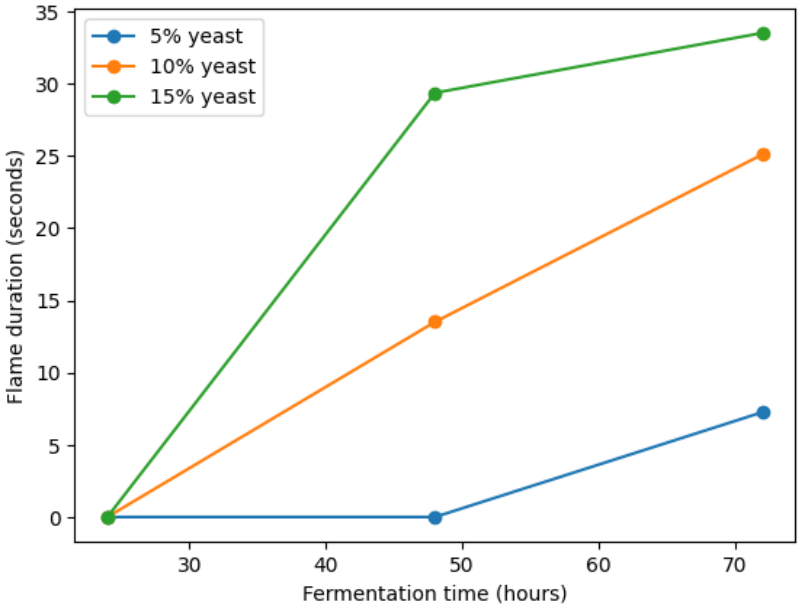

Figure 1. Effect of yeast concentration and fermentation time on the flame duration of bioethanol gel

Based on Figure 1, the flame duration of bioethanol gel increases with increasing yeast concentration and fermentation time. At 24 hours of fermentation, none of the samples produced a flame, indicating that ethanol production was still insufficient. A noticeable increase in flame duration was observed at 48 hours of fermentation, particularly at yeast concentrations of 10% and 15%. The longest flame duration was obtained at a yeast concentration of 15% with a fermentation time of 72 hours, reaching 33.52 seconds, which indicates the most optimal fermentation condition for ethanol production.

In addition to flame duration enhancement, the results indicate that yeast concentration plays a crucial role in determining the rate and efficiency of the fermentation process. A higher yeast concentration provides a greater number of microorganisms to convert sugars into ethanol, leading to increased ethanol accumulation in the fermentation medium. This explains why a yeast concentration of 15% resulted in higher flame duration and calorific value compared to lower yeast concentrations. Nevertheless, excessive yeast concentrations should be carefully controlled to avoid nutrient competition that may reduce fermentation efficiency.

Furthermore, the presence of a gelling agent such as carboxymethyl cellulose (CMC) influences the combustion characteristics of bioethanol gel. The results demonstrate that bioethanol gel containing CMC exhibits a higher calorific value than bioethanol without CMC. This can be attributed to the role of CMC in enhancing gel structure stability and reducing the evaporation rate of ethanol during combustion, allowing more efficient energy release. Therefore, the performance of bioethanol gel is influenced not only by ethanol content but also by the formulation and composition of added materials.

3.2. Bomb calorimeter

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Table 2. Calorific Value of Bioethanol Gel at Various Yeast Concentrations and Fermentation Times (cal/g)

Sample	Sample weight (g)		Average weight (g)	Calorific Value (Cal/g)		Average Calorific Value (cal/g)
	1	2		1	2	
P1 (5%, 72 hours)	1.46	1.41	1.44	791.92	505.02	648.47
P2 (10%, 72 hours)	1.48	1.48	1.48	2737.23	2777.04	2757.13
P3 (15%, 72 hours)	0.95	0.95	0.95	3367.56	3417.43	3392.49
P4 (15%, 72 hours non CMC)	0.97	0.97	0.97	3126.78	2973.18	3049.98

The table below illustrates the relationship between samples (P1, P2, P3, and P4) and their average calorific value. The average calorific value, expressed in calories per gram (cal/g), indicates the amount of energy each sample can release upon combustion.

The table below shows a correlation between samples (P1, P2, P3, and P4) and their average calorific value. In general, the average calorific value in calories per gram (cal/g) provides an indication of the energy released when the samples are tested based on the combustion process. This is crucial in chemical analysis, especially when determining the effectiveness of a particular material or mixture.

Increase in calorific value at the initial concentration (P1 to P3). The graph shows a significant increase in calorific value from P1 to P3. Sample P1 had the lowest calorific value, while P3 reached its highest peak calorific value. This indicates that increasing bioethanol concentration from P1 to P3 is directly proportional to the increase in calorific energy produced. This phenomenon can be attributed to effective fermentation optimization up to a certain point, where the available substrate supports maximum energy production. P1 lasted 24 hours, while P3 lasted 72 hours. Calorific value decreased at high concentrations (p4). In P4, a decrease in calorific value was observed compared to P3. This decrease was due to the absence of carboxymethyl cellulose (CMC) in sample P4.

A fermentation duration of 72 hours appears optimal for producing the highest calorific value in P3. Extending the fermentation time may increase bioethanol degradation due to the activity of microorganisms that produce by products, such as organic acids. The calorific value of bioethanol is highly dependent on the fermentation process and the characteristics of the feedstock. The peak calorific value at P3 indicates optimal conditions for the activity of ethanol-producing microorganisms, such as Saccharomyces cerevisiae [11].

Figure 2 shows that the calorific value of bioethanol gel is influenced by yeast concentration and the presence of a gelling agent. Sample P3 (15% yeast, 72 hours fermentation) exhibited the highest calorific value of 3392.49 cal/g, indicating a higher energy content compared to other samples. Although sample P4 had the same yeast concentration, its calorific value was lower, suggesting that the addition of CMC contributes to improved combustion stability and energy output. These results confirm that higher yeast concentration combined with optimal fermentation time significantly enhances the quality of bioethanol gel.

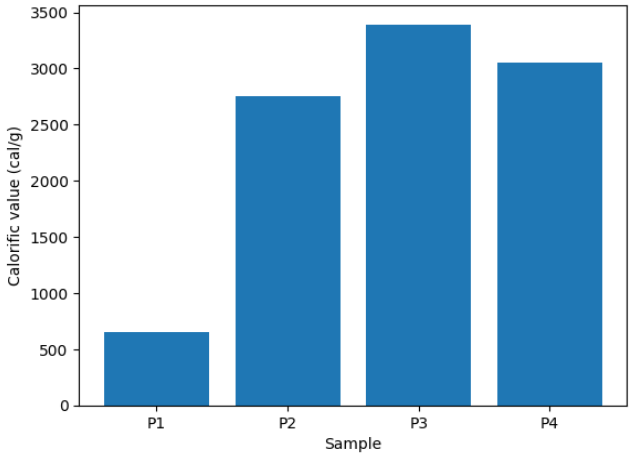

Figure 2. Calorific value of bioethanol gel at different sample variations

The results presented in Figure 2 indicate an increase in the calorific value of bioethanol gel with increasing yeast concentration at the same fermentation time. Sample P1 with a yeast concentration of 5% exhibited the lowest calorific value, suggesting that ethanol production was not optimal under these conditions. In contrast, increasing the yeast concentration to 15% in sample P3 resulted in the highest calorific value, indicating a more effective conversion of sugars into ethanol. A higher calorific value reflects greater energy content, thereby enhancing the potential of bioethanol gel as an alternative fuel.

A comparison between samples P3 and P4 reveals the influence of the gelling agent carboxymethyl cellulose (CMC) on the calorific value of bioethanol gel. Although both samples were produced using the same yeast concentration and fermentation time, the sample without CMC (P4) showed a lower calorific value than the sample containing CMC (P3). This suggests that CMC contributes to improved combustion stability and reduces energy loss during burning. Therefore, proper formulation of bioethanol gel, including the use of suitable additives, plays a crucial role in enhancing its energy efficiency and combustion performance.

3.3. Bioethanol gel standardization

Table 3. Physical and Chemical Characteristics of Fermented Bioethanol Gel

Tested standards	**Mark**
GCMS test result	76.53%
Ph	7.0
Viscosity at temperature 25 °C	0.907 mPa·s

The GCMS test results showed a primary compound content of 76.53%, predominantly ethanol. This value indicates that the sample has a fairly good purity, but is not yet optimal for some industrial applications. In the context of transportation fuels, this percentage meets the minimum requirements for blended fuels such as E20 or E30. However, for applications requiring high purity, such as the pharmaceutical industry or pure ethanol fuel, this value still needs to be increased to above 95%. The 23.47% impurities likely originate from water, methanol, or other organic compounds formed during the fermentation and distillation processes. Further identification of the composition of these impurities is essential for determining the appropriate purification method.

The pH value of 7.0 indicates a neutral condition in the bioethanol sample. This characteristic is highly advantageous because it minimizes the risk of corrosion in storage equipment and fuel systems. In the context of applications, a neutral pH makes the fuel more stable and safe for long-term use. However, it should be noted that a neutral pH does not necessarily guarantee the absence of certain contaminants, such as heavy metals or undetectable organic compounds. For specialized applications such as aviation fuel or medical applications, more rigorous pH monitoring and additional testing for specific contaminants may be necessary [12].

The sample viscosity of 0.907 cP indicates reasonably good flow characteristics. This value is slightly lower than that of pure ethanol (1.2 cP), likely due to the presence of water or other volatile compounds. In fuel applications, this low viscosity offers several advantages, including ease of fuel injection and blending with fossil fuels. However, caution should be exercised as too low a viscosity can affect the lubrication of some engine components. Therefore, if this sample is to be used as a pure fuel, consideration should be given to adding additives to modify its viscosity properties.

High bioethanol purity also reflects the success of the fermentation and distillation processes. Factors such as substrate type, fermentation conditions, and purification process efficiency significantly influence these results [13]. Lignocellulose-based substrates such as rice straw or bagasse can produce high-quality bioethanol if the enzymatic hydrolysis and fermentation processes are carried out optimally. Therefore, this value of 76.53% can be attributed to the effectiveness of the production process and the selection of appropriate raw materials.

A pH value of 7.0 indicates that the sample is neutral. This is a good result for bioethanol products, as a neutral pH is important to prevent corrosion in storage tanks and distribution lines [14]. Bioethanol with a pH outside the range of 6.5-7.5 can cause damage to metal materials that come into direct contact with it. Apart from that, a stable pH also shows that the fermentation and distillation process has been carried out with good control over the accumulation of organic acids, such as acetic acid.

Neutral pH values are also relevant in the context of blending bioethanol with fossil fuels. a mixture of bioethanol and gasoline with a pH close to neutral shows better chemical stability compared to an acidic mixture. This is important to maintain engine performance and reduce the formation of carbon deposits in the combustion chamber.

The sample viscosity of 0.907 indicates a low level of viscosity, which is an important characteristic for liquid fuels. Low viscosity ensures smooth flow within the fuel injection system, thereby increasing combustion efficiency. the viscosity of bioethanol ranges from 0.8 to 1.0 mPas at room temperature, which is considered ideal for fuel applications. Viscosity also affects the blending process with other fuels. Bioethanol with low viscosity tends to mix more easily and homogeneously with gasoline, resulting in a more stable mixture [15].

4. Conclusion

1. Based on the research results, it can be concluded that janeng starch (*Dioscorea hispida*) has significant potential as an alternative raw material for the production of bioethanol gel. The hydrolysis process using water has been shown to produce a substrate that can be fermented effectively by local yeast.

2. Variations in yeast concentration and fermentation time significantly influenced the characteristics of the resulting bioethanol. Fermentation for 72 hours with a yeast concentration of 15% (sample P3) yielded the best performance, demonstrated by the longest burning time and the highest calorific value of 3392.49 cal/g. This indicates that these conditions are optimal for the activity of ethanol-producing microorganisms.

3. Characterization results showed that the resulting bioethanol had an ethanol content of 76.53% and a neutral pH (7.0). A neutral pH is advantageous because it minimizes the risk of corrosion in fuel storage and distribution systems and increases the stability of the bioethanol for long-term use.

4. The addition of carboxymethyl cellulose (CMC) has been shown to increase the calorific value of gel bioethanol compared to liquid bioethanol without CMC, thus making gel bioethanol have greater potential as a safe, stable, and easily applicable alternative fuel.

5. Overall, this research demonstrates that gel bioethanol based on janeng starch using local yeast is a promising innovation as a renewable, environmentally friendly energy source, with the potential to support energy security and increase the economic value of non-food crops.

5. Suggestions

1. Further optimization of fermentation conditions is needed.

Further research is recommended to optimize fermentation variables such as temperature, initial pH, and additional nutrient concentrations to maximize Saccharomyces cerevisiae activity and produce higher bioethanol content.

2. Further testing of bioethanol purity is needed.

In addition to measuring pH and basic physical properties, further analysis is recommended, including water content, residual sugar, and other impurities, to ensure bioethanol quality meets fuel standards.

3. Variations in lignocellulosic feedstocks can be developed.

Further research can use other abundant and inexpensive alternative feedstocks to compare fermentation efficiency and the characteristics of the resulting bioethanol.

4. Bioethanol performance testing in real-world applications.

The resulting bioethanol should be further tested in combustion systems or fuel blends (e.g., gasohol) to determine its effects on engine performance and exhaust emissions.

5. Quality control and safety testing need to be improved.

Although the pH of bioethanol is neutral, additional testing for potential contaminants such as heavy metals or other organic compounds is recommended, especially if the bioethanol is intended for long-term or specialized applications.

Declarations

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Competing Interests Statement

The authors have declared that no competing financial, professional or personal interests exist.

Consent for publication

All the authors contributed to the manuscript and consented to the publication of this research work.

Availability of data and material

Supplementary information is available from the authors upon reasonable request.

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