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Bioethanol Characteristics of Musa Paradisiaca Artocarpus Peel

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ABSTRAK

Tujuan dari penelitian ini untuk (1) menganalisis karakteristik sifat kimia bioetanol (kadar etanol, metanol, air, Cu, keasaman, Cl, sulfur, getah), (2) menganalisis sifat fisika bioetanol (densitas, viscositas kinematik, titik nyala, nilai kalor, titik didih, pH dan angka oktan) dan (3) and (3) biaya produksi untuk memproduksi 1 liter bioethanol. *Untuk mendapatkan data yang sesuai dengan tujuan penelitian melalui metode eksperimen. Bahan baku kulit mussa paradica artocarpus, melalui proses sakarifikasi, fermentasi, dan distilasi. Bahan baku kulit mussa paradica artocarpus 500 gram, ragi 25 gram, kadar orea 20 gram. fermentasi 4 hari dan distilasi 5 tingkat dengan suhu 78°C dengan adsorben batu apung dengan mesh 70. Untuk uji karakteristik sifat kimia bioethanol menggunakan standar uji ASTM (kadar etanol D5501, methanol D5501, air D1744, Cu D1688, keasaman D1613, Cl D512, sulfur D2622 dan getah D381). Sedangkan uji karakteristik sifat-sifat fisika bioetanol menggunakan standar uji ASTM (densitas D 1298, viscositas kinematik D 445, titik nyala D 93, nilai kalor D 240, titik didih t D 2892, pH D6423 dan angka oktan D976). Hasil analisis sifat kimia biotanol menunjukkan bahwa kandungan etanol 99,65%, kandungan metanol 0,02%, kandungan air 0,01% vol, kandungan Cu 0,02 mg/kg, keasaman 19 mg/l, kandungan Cl 16,75 mg/l, kandungan belerang 0,01 mg/l dan kandungan getah 1,02 mg/100 ml. Sedangkan hasil dari analisis sifat fisika menunjukkan bahwa densitas 0,787 g/cm³, viscositas kinematik 1,28 cSt, titik nyala 18°C, titik didih 78°C, nilai kalor 6985 kkal/kg, pH 6,9mg/l, dan nilai oktan 107.* Biaya produksi untuk memproduksi 1 liter bioethanol dari kulit *musa paradisiaca artocarpus* dengan kandungan 99.65%-v etanol sebesar Rp.47,782,-.*Secara keseluruhan, bioetanol ini menawarkan kinerja yang sangat baik dan bermanfaat untuk lingkungan, sehingga layak sebagai pengganti atau campuran bahan bakar bensin.*

Kata Kunci : *bahan bakar terbarukan, mussa paradica artocarpus, bioetanol, batu apung.*

ABSTRACT

The objectives of this research are to analyze the chemical and physical properties of bioethanol as well as production costs. Data were collected using experimental methods. The raw material, musa paradisiaca artocarpus Peel, was processed through saccharification, fermentation, and distillation. The experiment used 500 grams of peel, 25 grams of yeast, and 20 grams of urea, with fermentation lasting four days and five-stage distillation conducted at 78°C, utilizing pumice stone adsorbent with a 70-mesh size. Chemical properties of the bioethanol were tested using ASTM standards: ethanol content (D5501), methanol content (D5501), water content (D1744), copper (D1688), acidity (D1613), chloride (D512), sulfur (D2622), and gum content (D381). Physical properties were tested using ASTM standards: density (D1298), kinematic viscosity (D445), flash point (D93), heating value (D240), boil point (D2892), pH (D6423), and octane number (D976). The results of the chemical property analysis showed that the bioethanol contained 99.65%-v ethanol, 0.02% methanol, 0.01% water, 0.02 mg/kg copper, 19 mg/l acidity, 16.75 mg/l chloride, 0.01 mg/l sulfur, and 1.02 mg/100 ml gum. The physical property analysis results revealed a density of 0.787 g/cm³, kinematic viscosity of 1.28 cSt, flash point of 18°C, boiling point of 78°C, heating value of 6985 kcal/kg, pH of 6.9, and an octane number of 107. Production costs for producing 1 litre bioethanol from musa paradisiaca artocarpus Peel with 99.65%-v ethanol content costs Rp.47,782,. Overall, this bioethanol offers excellent performance and environmental benefits, making it a viable alternative to as a substitute or a mixture of gasoline fuels.

Keywords*: renewable fuel, musa paradisiaca artocarpus Peel, bioethanol, pumice stone.*

INTRODUCTION

The rapid development of industries and transportation has significant impacts on health and the availability of fossil fuel energy. These impacts include increased air pollution, global warming, deteriorating human health, rising air temperatures, acid rain, and the depletion of oil reserves, potentially leading to an energy crisis [1, 2]. Therefore, it is crucial to find renewable, sustainable, affordable, and environmentally friendly alternative fuels with readily available raw materials. A suitable alternative fuel to replace gasoline is bioethanol [3, 4]. Bioethanol has characteristics similar to gasoline, making it highly suitable as a blend or replacement for gasoline [5]. Bioethanol is a type of alcohol produced through fermentation and multi-stage distillation of materials containing carbohydrates, sugars, starch, and fibers, such as sugarcane, corn, bananas, wheat, cassava, fruits, rice, rice husks, bran, and other agricultural by-products [6]. As an agrarian country, Indonesia has abundant raw materials for bioethanol production, sourced from plants, fruits, and biomass [7].

One of the potential raw materials for bioethanol production is the peel of Musa paradisiaca (banana). Although banana peel is a fruit residue, it can be effectively utilized as a raw material for bioethanol production [8]. Banana peel waste contains 59% carbohydrates, 31.7% crude fiber, 78.1% potassium, 19.2% calcium, 24.3% iron, and 24.3% manganese [9]. According to Musita [10], the resistant starch content in the peel of Musa paradisiaca is 30.66%, while that of plantain (Musa acuminata) is 29.60%. Research by Fariha et al. [11] revealed that banana peel flour from Musa paradisiaca contains 83.31% carbohydrates and 14.58% cellulose.

Bioethanol is a type of alcohol produced through fermentation and multi-stage distillation to achieve high-quality bioethanol [12]. Distillation requires a high-quality adsorbent with high porosity to maximize water absorption. One of the highly absorbent and easily obtainable adsorbents is pumice stone [13]. Pumice is a light-colored rock composed of frothy material formed from glass-walled bubbles, often referred to as volcanic silicate glass rock [13]. Pumice has a porous structure with numerous fine capillaries, allowing the adsorbate to be absorbed within these capillaries [14]. The efficiency of pumice as an adsorbent is reported to be as high as 90% [15].

Bioethanol production from the Peel of a banana has been done by some researchers including: Singh, *et al*., [16] the research *bioethanol production from banana peel by simultaneous saccharification and fermentation process using cocultures aspergillus niger and saccharomyces cerevisiae*. By discussing bioethanol production with aspergillus niger, with vulnerable pH, 4, 5, 6 and 7. The temperature of 20°C, 30°C, 40°C, 50°C and yeast concentration 3%, 6%, 9%, 12%. Results of this study show the optimal temperature and pH in the fermentation process its temperature is 30°C with pH 6. Herliati, et al., [17] in his research utilizing banana Peel waste as a raw material. Bioethanol production with fermentation using saccharomyces cereviciae 3%, long time 2 6, 8 days, fermentation temperature 30°C and 40°C with ph between 4 and 5 with level 4 distillation. Results show that the ethanol content is 86.35 % -v with a temperature of 40°C, pH 4 and long fermentation time 6 days. Bahri, et al, [18] the production of bioethanol from banana *kepok* Peel through fermentation using bread saccharomyces. Banana *kepok* Peel hydrolysis capped using HCl % with 100^{o}C temperature and 90 minutes long hydrolysis time. Variety of volume starter 100, 200, 300 and 400 ml and fermentation time 4, 6, 8 and 10 days. Distillation to level 3. The best results of this study are with variations of volumes 400 ml and a long time of fermentation 8 days with yield 19,75 % and ethanol content 57%-v. Furthermore Hikmah et al [19] this study the manufacture of bioethanol from banana *kepok* Peel. The hydrolysis process with temperature variations of 60°C, 80°C, and 100°C. The hydrolysis solution is fermented with yeast variations, namely *fermipan* and yeast tape (4 grams, 8 grams, and 12 grams) with the addition of NPK 4 grams and 5 gram urea. The result shows glucose levels were obtained at 60°C, namely 33.0%, at 80°C, 41.2% and temperatures of 100°C, 56.0%. The results of fermentation solutions obtained by the concentration of ethanol in *fermipan* with a weight of 4 grams, 8 grams and 12 grams respectively 0.264%, 0.630% and 0.786% while the concentration of ethanol in the tape yeast weighs 4 grams, 8 grams, and 12 grams successively which are 0.015%, 0.006% and 0.017%. While Febriana et al [20] result of the research, it can be seen that the sample of banana leaf waste (musa balbisiana) produces the most bioethanol with yeast bread type at incubation temperature 30˚C that is 0,5854%, then banana *kepok* (paradisiaca L) and king banana leather (musa sapientum) with each bioethanol content of 0.4587%-v and 0.4173%-v. While another research Bilyartinus and Siswanto [21] this research to

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investigate the effect of bacillus subtilis in the fermentation of bioethanol production from ambon banana peels. The methods used were pretreatment, hydrolysis, fermentation, and distillation. Bacillus subtilis and saccharomyces cerevisiae ratio (10: 5 and 5: 5) use for obtaining high ethanol yields, as well as variations in pH 2 and 6 in the fermentation starter. The variable were designed by using factorial design. The result shows the yeast ratio of B. subtilis and S. cerevisiae (10: 5) resulted in the highest concentration of bioethanol (6%) in 6 days. In acidic conditions (pH 2), the bacteria don't gow optimally. The higher concentration of bioethanol (6%-v) was reached in pH 6. As well as Bakhor and Muhaji [22] bioetanol production of tuber stem musa paradisiaca. Variation of the zeolite absorben 6, 7, 8 grams of 120°C warming temperatures. The process at a temperature 100°C saccharification, 4 days fermentation, yeast saccharomyces cerevisiae 7 grams, water 1000 ml, tuber stem excrescence 500 grams and the distillation of 5 level at a temperature of 78 °C. The result of research shows that a heavy an adsorbent levels reached 7 grams and purity of bioetanol 99,46 %. In addition, Maulana et al [23] bioethanol production from the Peel of a banana kapok by means of hydrolysis, fermentation and distillation with temperature variations hydrolysis 80°C, 90°C and 100 °C. Concentration variation catalyst H_2SO_4 1 mol, 2 mol, 3 mol with fermentation time 5, 7, 9 days. The result of the research indicated that the yield and the highest density at a temperature 90°C of hydrolysis, the catalyst H_2SO_4 3 mol with long fermentation 9 days of 5,0432 % and 0,8346 gr/ml. Thus, this study aims to elucidate the chemical and physical properties characteristics of *musa paradisiaca artocarpus* Peel bioethanol, which are important as the major alternative source of fuel.

METHOD

Materials, Equipment, and Laboratory Testing Standards

The raw materials used include musa paradisiaca peel, saccharomyces cerevisiae, urea fertilizer, pumice stone, and water. Bioethanol production involves saccharification, fermentation, and distillation processes. The raw materials consist of 500 grams of *musa paradisiaca artocarpus* Peel, 25 grams of yeast, and 20 grams of urea fertilizer. The fermentation process lasts for 4 days, followed by a five-stage distillation at 78°C, utilizing pumice stone as the adsorbent with a 70-mesh size.

The chemical properties of bioethanol were analyzed using ASTM standards: ethanol content (D5501), methanol content (D5501), water content (D1744), copper (Cu) content (D1688), acidity (D1613), chloride (Cl) content (D512), sulfur content (D2622), and gum content (D381). Meanwhile, the physical properties of bioethanol were tested using ASTM standards: density (D1298), kinematic viscosity (D445), flash point (D93), heating value (D240), boil point (D2892), pH (D6423), and octane number (D976).

Fractional Distillation Equipment Series

The experimental setup and instruments are illustrated in Figure 1.

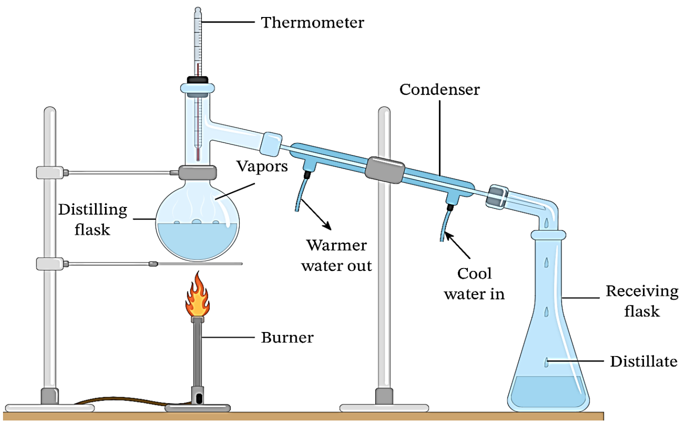

Figure 1. The Setup of Distillation Equipment

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Bioethanol Production

The experimental bioethanol production is illustrated in Figure 2.

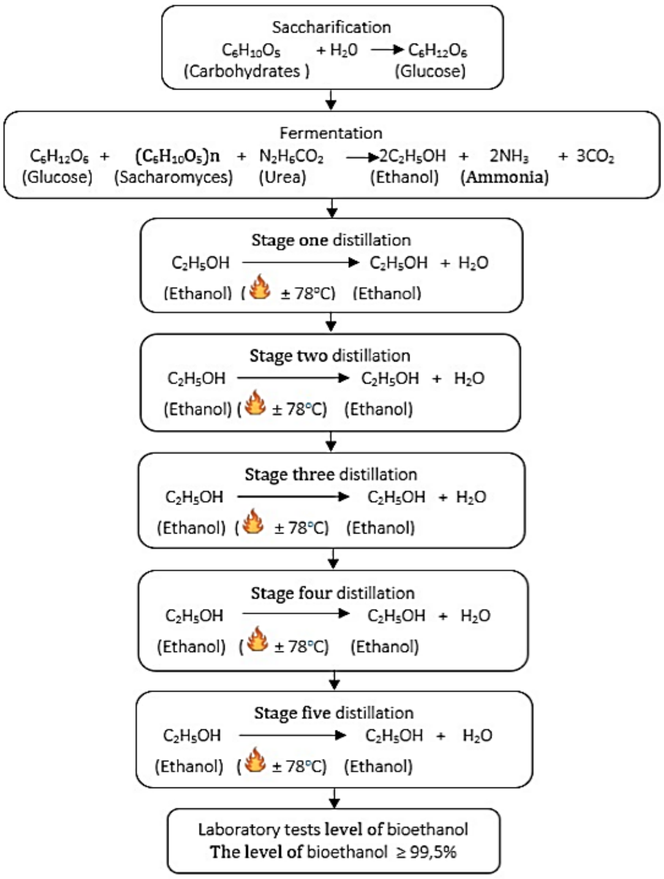

Figure 2. Flowchart Bioethanol Production

RESULTS AND DISCUSSION

The bioethanol (C_2H_5OH) produced from Musa paradisiaca peel through saccharification, fermentation, and distillation processes was subjected to chemical and physical property testing in the laboratory. The results are presented in Tables 1 and 2. The laboratory test results for the chemical properties of bioethanol derived from Musa paradisiaca peel are shown in Table 1.

Table 1. The results of laboratory tests on bioethanol chemical properties

No	Chemical Properties	Method	Bioethanol Standart	The Results of Laboratory Tests
1	Ethanol contens (%-v min)	ASTM D5501	99.5	99.65
2	Methanol contens (%-v max.)	ASTM D5501	0.5	0.01
3	Water contens (%-v max)	ASTM D1744	0.7	0.02
4	Copper contens (mg/kg max)	ASTM D1688	0.1	0.01
5	Acidity contens CH_3COOH (mg/l max)	ASTM D1613	30	21
6	Clroride contens (mg/l maks)	ASTM D512	20.0	15.05
7	Sulfur contens (S) (mg/l max)	ASTM D2622	50	0.02
8	Gum contens (mg/100 ml) max)	ASTM D381	5.0	1.1

The laboratory test results presented in Table 1 were subsequently converted into bar charts, as shown in Figures 3–10.

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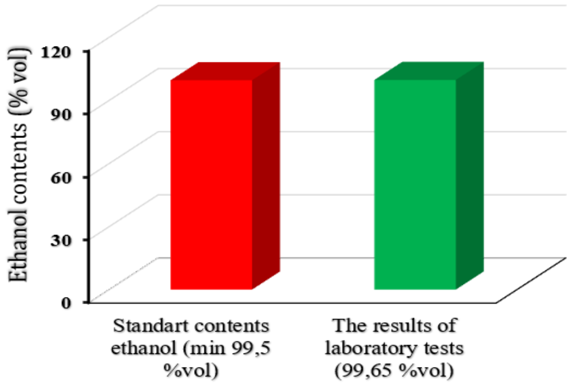

Figure 3. Ethanol Contents

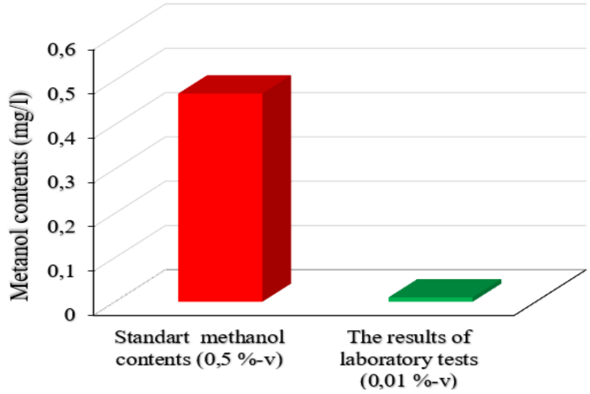

Figure 4. Methanol Contents

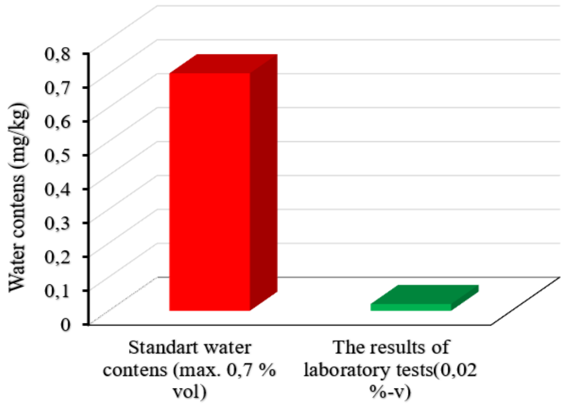

Figure 5. Water Contents

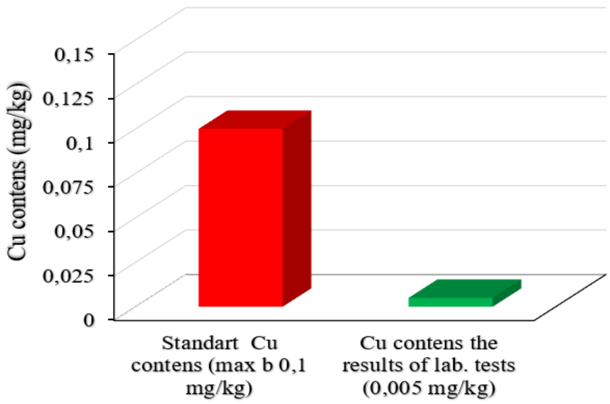

Figure 6. Copper Contents

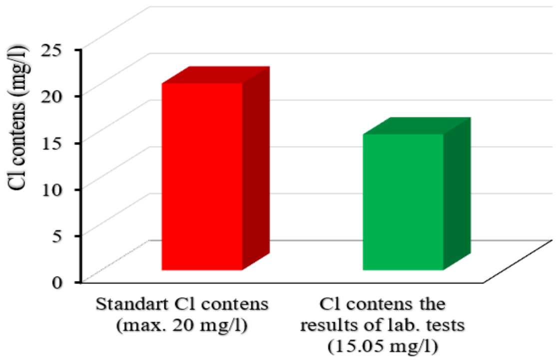

Figure 7. Acidity Contents

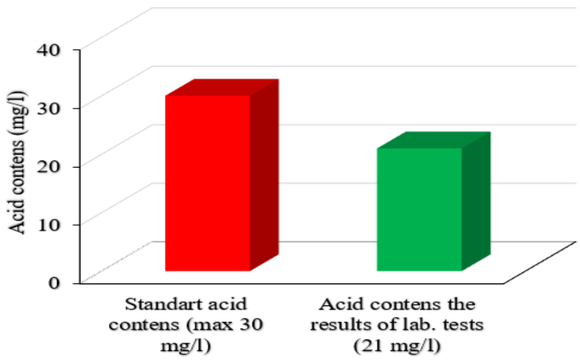

Figure 8. Cloride Contents

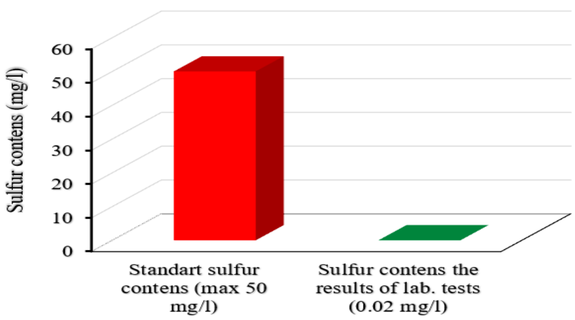

Figure 9. Sulfur Contents

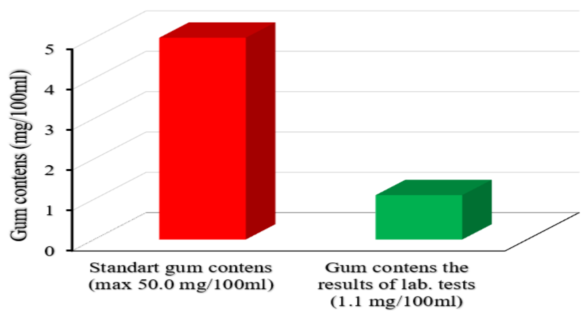

Figure 10. Sulfur Contents

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Table 1 and Figures 3–10 present the laboratory test results for the chemical properties of bioethanol derived from Musa paradisiaca peel, produced through saccharification, fermentation, and five-stage distillation. The laboratory analysis indicates that the ethanol content is 99.65%-v, surpassing the Indonesian National Standard (SNI) requirement of 99.5%-v, confirming that the bioethanol meets the standard. The high ethanol content is influenced by enzyme activity and the fermentation duration [24, 25, 26]. Additionally, multi-stage distillation plays a significant role, as higher distillation levels yield higher ethanol concentrations [25/ 22].

The methanol content is exceptionally low at 0.01%-v, compared to the SNI standard of 0.5%-v. This is attributed to sugar consumption and yeast growth during fermentation [27]. This result is noteworthy as it indicates a high level of safety and quality in the produced bioethanol. The fermentation and distillation processes likely played a crucial role in achieving such low methanol levels. Methanol is typically formed during the breakdown of pectin in lignocellulosic materials. However, controlled fermentation conditions (e.g., pH, temperature, and yeast selection) can minimize its production [28]. The choice of raw materials (Musa paradisiaca and Artocarpus Peel) may also contribute to the low methanol content. These substrates might have lower pectin levels compared to other biomass sources, resulting in reduced methanol formation during fermentation [28,29]. Additionally, advanced distillation techniques could have effectively separated methanol from ethanol due to their differing boiling points, ensuring a purer final product [29, 30]. The significance of the findings lies in several key aspects. First, the low methanol content aligns with global safety standards for bioethanol use in fuel applications, enhancing its suitability for widespread adoption [30]. Additionally, this reduced methanol content contributes to cleaner combustion with minimal toxic emissions, thereby supporting sustainability goals and reducing environmental impact [29, 30]. Furthermore, the results indicate that bioethanol derived from these specific raw materials can meet stringent quality standards, making it highly competitive with other biofuels in the market [28].

The water content in the bioethanol is very low at 0.02%-v, significantly below the SNI standard of 0.7%-v. This reduction is influenced by enzyme efficiency and the quality of the pumice adsorbent used, which is highly porous. The use of minimal enzymes during fermentation reduces the water content in the bioethanol [31]. Furthermore, the larger and more porous the adsorbent, the greater its water absorption capacity, resulting in lower water content [22]. A lower water content in bioethanol typically leads to better fuel efficiency. Water can dilute the energy content of ethanol, leading to suboptimal performance in engines designed for high-purity fuels. The low water content observed (0.02%-v) suggests that this bioethanol could provide more energy per volume compared to those closer to the SNI limit. Bioethanol with low water content is less prone to microbial growth and degradation during storage. This stability is crucial for maintaining fuel quality over time, especially in regions where storage conditions may not be ideal [32]. The significantly low water percentage enhances the shelf life and usability of the bioethanol.

The copper (Cu) content in the bioethanol is also very low at 0.01 mg/kg, compared to the SNI standard of 0.1 mg/kg. This is affected by the fermentation and distillation equipment used [22, 33]. The type of feedstock used in bioethanol production can affect the final copper levels. Some raw materials may naturally contain higher levels of trace metals, including copper, which can carry over into the final product [34]. The fermentation and distillation processes play a significant role in determining trace metal retention in bioethanol. Proper management of these processes can help minimize unwanted metal contaminants [35]. High levels of copper in biofuels can lead to corrosion of metal components in engines and storage systems. Copper can catalyze the oxidation of ethanol, leading to the formation of harmful byproducts that may damage engine parts over time [36]. The very low copper content of 0.01 mg/kg significantly reduces this risk, enhancing the longevity and reliability of equipment using this bioethanol. Low copper levels contribute to better fuel quality by minimizing the potential for undesirable chemical reactions during combustion. High copper concentrations can lead to increased emissions and reduced combustion efficiency, which are detrimental to engine performance [37]. The low copper content in this bioethanol suggests improved combustion characteristics and lower emissions.

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The acid content is 21 mg/l, well below the SNI maximum of 30 mg/l, indicating good quality and suitability for use as a fuel. The low acidity not only enhances fuel performance but also reduces potential corrosive effects on engines and storage systems.

The temperature, pH, and duration of fermentation can affect the production of organic acids during ethanol fermentation [38]. Different raw materials have varying inherent acid levels. For example, sugarcane and corn may yield different acidity profiles due to their biochemical compositions [34]. The efficiency of the distillation process can also impact acid removal from the final product. Proper distillation techniques can help minimize residual acids [35].

The chloride ion (Cl) content is 15.05 mg/l, lower than the SNI standard of 20.0 mg/l. This is impacted by the reaction speed during hydrolysis, where faster hydrolysis reactions result in lower chloride content [18]. Lower chloride ion levels are beneficial as chlorides can lead to corrosion of metal parts in engines and fuel systems. High chloride concentrations can accelerate the degradation of materials, leading to increased maintenance costs and reduced lifespan of engine components [36]. A measurement of 15.05 mg/l suggests a reduced risk of corrosion, enhancing the longevity and reliability of the equipment. Chloride ions can negatively impact the stability and quality of bioethanol. High levels may lead to phase separation or other chemical reactions that degrade fuel quality over time [37]. The low chloride content in this bioethanol indicates better stability, making it more suitable for storage and use.

The sulfur (S) content is very low at 0.02 mg/l, far below the SNI maximum of 50 mg/l, due to the low sulfur content in the raw materials. The type of feedstock used can greatly affect the sulfur levels in the final product. Some raw materials may contain higher natural sulfur concentrations, which can carry over into the bioethanol during production [34]. Low sulfur content in bioethanol is crucial for reducing air pollution. Sulfur compounds can lead to the formation of sulfur oxides, which contribute to acid rain and respiratory problems in humans. By maintaining a sulfur level of only 0.02 mg/l, this bioethanol minimizes its environmental footprint and aligns with global efforts to reduce emissions from fossil fuels [37].

Finally, the gum content in the bioethanol is 1.1 mg/100 ml, significantly lower than the SNI standard of 5.0 mg/100 ml. This is influenced by the gum content in the raw materials used for bioethanol production. The type and quality of feedstock used in bioethanol production can affect gum formation. Certain raw materials may predispose the final product to higher gum levels due to their chemical composition [34]. The fermentation and distillation processes play a significant role in determining gum retention in bioethanol. Proper management of these processes can help minimize the formation of gums [35]. Low gum content is beneficial for the stability of bioethanol during storage. Gums are typically formed from oxidation or polymerization reactions that can occur over time, leading to phase separation or sediment formation. The low level of 1.1 mg/100 ml suggests that this bioethanol will maintain its quality over extended periods, reducing the risk of fuel degradation [37]. High gum levels can lead to deposits on fuel injectors and combustion chambers, negatively impacting engine efficiency and performance. By maintaining a low gum content, this bioethanol minimizes the risk of fouling and ensures smoother operation of engines designed for high-quality fuels [36].

The laboratory test results for the physical properties of bioethanol derived from Musa paradisiaca peel are presented in Table 2.

Table 2. The results of laboratory tests bioethanol physical properties

No	Physical properties	Method	Bioethanol Standart	The Results of Laboratory Tests
1	Density 20˚C (g/cm^3)	ASTM D1298	0.789	0.791
2	Kinematic viscosity 20˚C (cSt)	ASTM D445	1.2-1.5	1.23
3	Flash point (^{o}C)	ASTM D93	12-20	19
4	Boil point (^{o}C)	ASTM D2892	80 max	77
5	Heating value (kcal/g)	ASTM D240	6424-7094	6978
6	pH (mg/l)	ASTM D6423	6.5-9.0	6.7
7	Octan number	ASTM D976	103	106

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The laboratory test results presented in Table 2 were subsequently converted into bar charts, as shown in Figures 11–17.

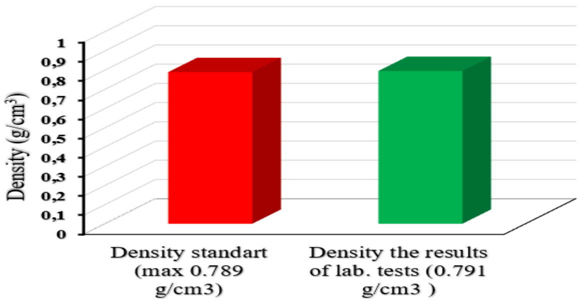

Figure 11. Density

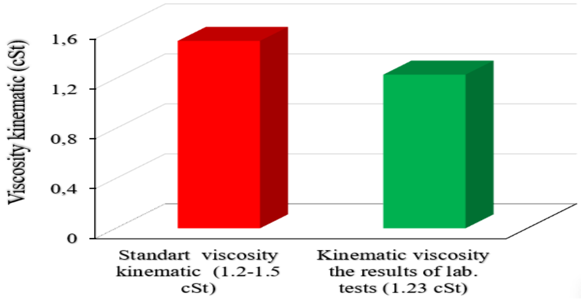

Figure 12. Viscosity Kinematic

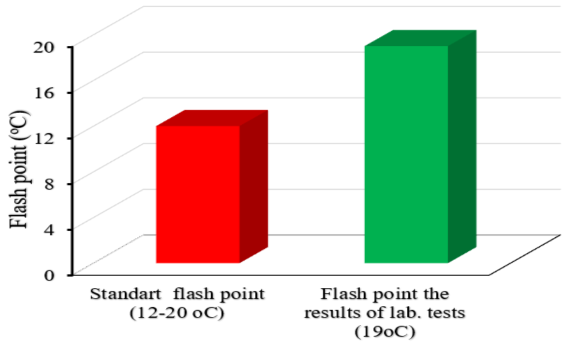

Figure 13. Flash Point

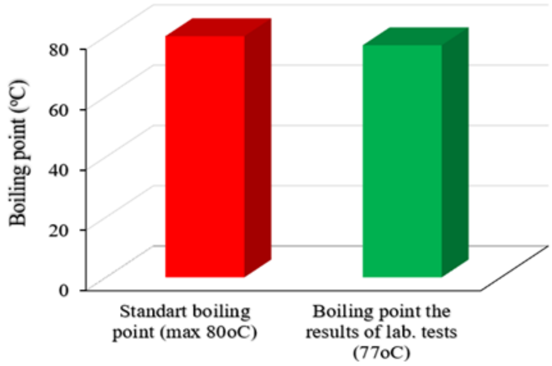

Figure 14. Boiling Point

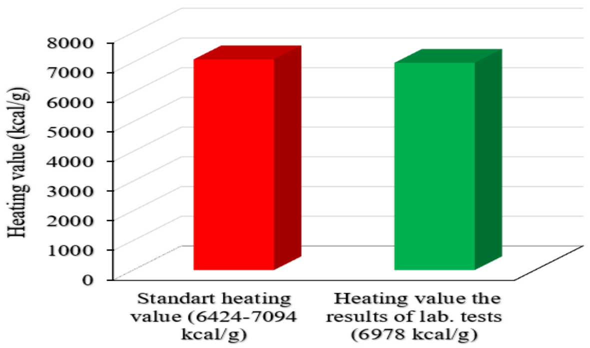

Figure 15. Boiling Point

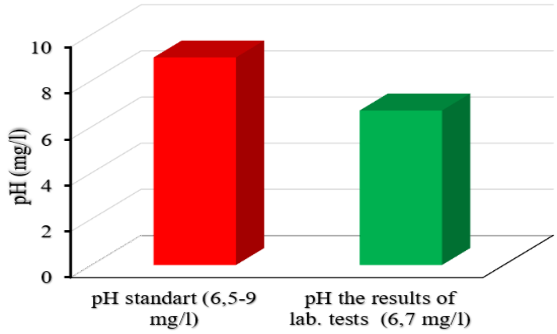

Figure 16. pH

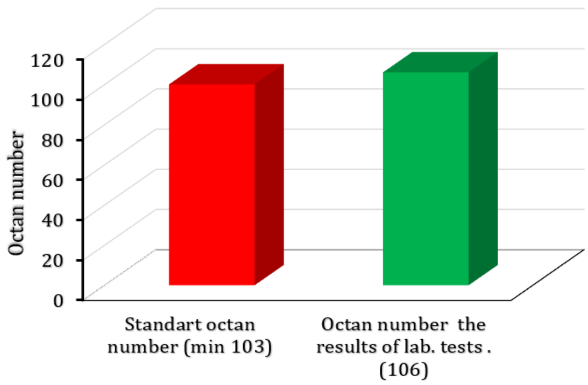

Figure 17. Octan Number

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The laboratory-tested density of bioethanol is 0.791 g/cm³, which is slightly higher than the SNI standard of 0.789 g/cm³. The density of bioethanol is influenced by the fermentation process, enzyme activity, hydrolysis conditions, and ethanol content. Higher ethanol content generally results in lower density [39]. The kinematic viscosity of bioethanol is 1.23 cSt, meeting the SNI standard range of 1.2–1.5 cSt. The viscosity is affected by fermentation duration, the quantity of starter used, and the presence of hydroxyl (-OH) groups, which exhibit polar characteristics [40]. The flash point of the laboratory-tested bioethanol is 19°C, within the SNI standard range of 12–20°C. The flash point is influenced by the evaporation rate, with faster evaporation leading to a lower flash point [41]. The boiling point of the bioethanol is 77°C, which complies with the SNI maximum standard of 80°C. The boiling point is affected by vapor pressure and fuel composition, higher vapor pressure results in a higher boiling point. The heating value of the bioethanol is 6975 kcal/g, indicating a high energy content. This is influenced by the carbon and hydrogen content of the raw material. Higher carbon and hydrogen levels lead to a higher heating value [42]. Additionally, ethanol concentration affects the heating value, with higher ethanol content correlating to higher energy output [43]. The pH of the bioethanol is 6.7, which meets the SNI standard range of 6.5–9.0. The pH is influenced by the fermentation duration, as extended fermentation increases alcohol production but decreases pH and gas production [44]. Lastly, the octane number of bioethanol is 105, exceeding the SNI standard of 103. This high-octane number is attributed to ethanol content, as higher alcohol concentrations result in higher octane ratings [45].

CONCLUSION

The bioethanol produced from Musa paradisiaca peel meets the Indonesian National Standard (SNI) requirements for both chemical and physical properties, demonstrating its potential as a high-quality renewable fuel. The ethanol content (99.65%-v) surpasses the SNI standard, and other parameters such as methanol, water, and impurities like sulfur and chloride are well within acceptable limits. The physical properties, including density, viscosity, boiling point, flash point, and heating value, align with or exceed the SNI standards, reflecting the efficiency of the production process. Factors such as enzyme activity, fermentation duration, multi-stage distillation, and the quality of adsorbents significantly influence bioethanol quality. Production costs for producing 1 litre bioethanol from *musa paradisiaca artocarpus* peel with 99.65%-v ethanol content costs Rp.47,782,-. Current price of ethanol in stores (in Chemical Indo Tandes Surabaya and CV Nirvana Abadi Surabaya) ethanol price of 96%-v - 98%-v ethanol content for Rp.60,000-rp.120,000,-/litre. Overall, this bioethanol offers excellent performance and environmental benefits, making it a viable alternative to as a substitute or a mixture of gasoline fuels. The result of this research is useful to study the development of knowledge fuel and renewable energy. The results of this study show that density and viscosity of the bioethanol are still above the specified standard, then to lower the density and viscosity can use the ethyl acetate mix at the distillation stage three to the last stage.

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