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Analysis of The Potential and Challenges of Developing Bagasse as Bioethanol Fuel

Hanabell Jovanka [1*], Frasisca Chiara Anindita [2]

[1] *Chemistry Study Program, Faculty of Mathematics and Natural Sciences, Brawijaya University*
[2] *Environmental Engineering Study Program, Faculty of Agricultural Technology, Brawijaya University*
Jl. Veteran, Ketawanggede, Kec. Lowokwaru, Malang, Jawa Timur, Indonesia 65145

Abstract

Bioethanol is an alternative energy source to fossil fuels derived from plant materials containing cellulose, such as sugarcane bagasse. According to data from the Ministry of Energy and Mineral Resources of the Republic of Indonesia, fuel consumption in Indonesia reached 29.68 million kiloliters in 2022. Transportation contributes the largest share of emissions at 80%. This study will review the potential and challenges of increasing bioethanol use as a 15% blend in non-diesel fuels by 2025. The research utilizes secondary data to produce solutions addressing these issues, concluding the overall analysis. The use of sugarcane bagasse as a bioethanol feedstock offers several advantages over traditional fuels, including (1) reducing carbon monoxide emissions by 19-25%, (2) lowering fuel costs, and (3) increasing octane value. Despite these benefits, bioethanol utilization faces challenges such as (1) the need for further research, (2) the requirement for advanced and expensive technology, and (3) raw material availability. Presidential Instruction No. 1/2006 emphasizes the need for biofuels, making this review essential. The study identifies steps to maximize the potential of bioethanol in reducing emissions and minimizing challenges.

Keywords*: bioethanol; fuel; transportation; sugarcane bagasse; cellulose*

1. Introduction

Amid a developing era, it is undeniable that the population has also increased. This then has an impact on increasing energy consumption, especially transportation fuel. Fuel consumption that increases yearly can impact the increase in exhaust fumes and the depletion of fossil fuels. Exhaust fumes from the transportation sector are carcinogenic, which can harm health, especially respiratory, even in small amounts. Data from the Ministry of Energy and Mineral Resources shows that 40% of final energy consumption comes from the transportation sector. Millions of cars in Indonesia produce more than 35 million tons of CO2 emissions, while trucks produce more than 50 million tons of CO2 emissions by 2024. This value is alarming because projections for the next few years show an increase that will impact global temperature rise (Dinanti et al., 2024).

Bioethanol is an alternative energy source that can be used as a substitute for fossil fuels to reduce the use of fossil fuels. Bioethanol is an alternative fuel from organic materials such as plants with high carbohydrate content. Bioethanol can reduce the emission gases produced by CO. Some countries pay more attention to bioethanol as a substitute for fuel oil because the residual combustion of bioethanol produces fewer greenhouse gases than fuel. In this study, researchers focused on using sugarcane waste as the primary raw material for bioethanol. The reason behind the use of sugarcane waste is because the cellulose content of sugarcane is relatively high. This content has excellent potential for use as an alternative energy.

The selection of sugarcane waste as a raw material for bioethanol is supported by several strong reasons. According to the Central Statistics Agency, Indonesia has around 490 thousand hectares of sugarcane land. East Java Province is the largest sugarcane producer, with an average production in 2018 - 2022 of 1,077,567 tons. The part of sugarcane that is processed into sugar is only the wet part of the stem by 10% - 15%, while the rest, namely sugarcane skin, will become waste. Bagasse waste, known as bagasse,

*) Corresponding Author
E-mail: hjovanka@student.ub.ac.id

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contains much lignocellulose, which can be used as alternative energy because it contains 24% lignin, 53% cellulose, and 20% hemicellulose. However, not all bagasse content can be fermented by microbes into biofuels. Before the bioethanol processing process, lignin in the bagasse must be removed first so that the hydrolysis process can run optimally. The process of making bioethanol is carried out by the process of hydrolysis of sugarcane (cellulose) into sugar, then the process of fermenting sugar into ethanol and followed by a distillation process to convert 15% ethanol to 95% (Arif et al., 2017; Dyani & Rosariawari, 2021).

In Presidential Instruction No. 1/2006, it is stated that biofuels are necessary as fuel, so this review needs to be carried out. This is also in line with the 2030 agenda for sustainable development or sustainable development goals (SDGs) with the goal of clean and affordable energy. Primary energy, such as fossil fuels, still dominates the total energy used in Indonesia; fossil energy contributes 38% of the total national energy use (Kementerian PPN, 2020). It is expected that by 2030, the contribution of primary energy in Indonesia will reach 12.1% (BAU scenario) and 26.1% (intervention scenario); this, of course, needs to get attention from many parties to achieve the renewable energy mix in Indonesia. Responsible consumption and production, such as using bagasse waste as bioethanol material, support the government's ambition to reduce waste production in Indonesia, such as using waste as an alternative energy resource. Climate change is estimated to contribute 57% of all total gas emissions by 2030; this needs to involve innovation from renewable energy, the availability of environmentally friendly transportation, optimization of energy use, and increasing biofuels such as bioethanol.

2. Research Methods

The research entitled "Analysis of the Potential and Challenges of Sugarcane Bagasse Development as Bioethanol Fuel" was studied using a qualitative approach. Research using this method focuses on in-depth observation and subjective data analysis. Subjective observation and analysis methods mean that the observation and analysis of data are subjective and avoid personal tendencies or biases. The data used in the study were obtained through literature studies and secondary data. A literature study is a method of collecting data by reading, recording, and managing data objectively. The data obtained from the literature study process will be reviewed critically, analytically, and systematically.

3. Research and Discussion

3.1. Bioethanol from Bagasse

Bioethanol is the result of the production of biomass in the form of ethanol. Sugary, starchy, and fibrous materials are the raw materials for manufacturing bioethanol. Plant pulp with high sugar and carbohydrate content, such as sugarcane, corn, bananas, and sweet potatoes, can be processed into bioethanol. The plant will undergo two reaction stages to become ethanol (Trisakti et al., 2015).

In **Figure 1,** *bagasse* produces two parts, *bagasse*, and sweet liquid, resulting from mill grinding. Bagasse comprises a matrix of cellulose and lignin with chain hemicelluloses binding them together. Chain hemicellulose consists of hemicellulose, lignin, and cellulose. Before sugarcane waste is processed, it needs to be sorted first. The bagasse will then be dried and crushed to powder form. Yeast can ferment the sweet liquid directly, breaking the sugar into CO2 gas and ethanol. After that, lignin will be degraded to separate from hemicellulose and cellulose. The hydrolysis process will convert cellulose into sugar. Lignin degradation causes direct contact between hemicellulose and cellulose with microorganisms for the fermentation process that produces 15% ethanol. Then, distillation is done to purify the ethanol to 95% (Arif et al., 2026; Masrur et al., 2023).

3.2. Potential Analysis

Utilization of bagasse into bioethanol fuel has several potentials, including being able to reduce carbon monoxide levels from combustion (19-25%), reducing fuel prices, and increasing octane value. Increasing the amount of transportation will produce gas emissions; of

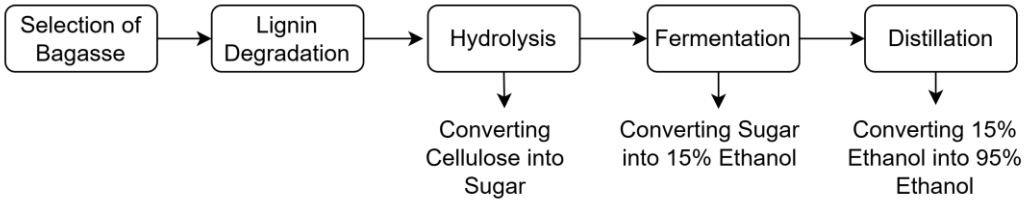

Figure 1. Flow chart of bioethanol production (Dyani & Rosariawari, 2021)

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course, it will harm the environment. Bioethanol development efforts can reduce the level of gas emissions caused. The high amount of gas emissions caused by the lack of oxygen levels makes gas combustion incomplete; bioethanol can reduce the concentration of carbon monoxide emissions.

In **Figure 2** and **Figure 3**, the use of BE5 can reduce emissions by 11.11% and 16.7% for BE10 with *gear* parameters. Meanwhile, using BE5 can reduce emissions by 18.75% and 43.75% for BE10 with rpm parameters. Bioethanol blends can reduce carbon monoxide concentrations but increase HC levels (Rifa et al., 2022).

Bioethanol is derived from various types of biomass, both food crops and lignocellulosic biomass. Agricultural waste, plantations, and forestry products can be used as raw materials for bioethanol. These wastes are in large quantities in various countries, especially Indonesia. Considering that Indonesia has an intense tropical climate in the agriculture, plantation, and forestry sectors, Indonesia can produce plants that can then be processed into bioethanol, such as sugar cane. This can impact the country's economy, where Indonesia produces bioethanol.

Using bioethanol as a fuel mixture can reduce fuel prices by reducing dependence on imported fuel products, which impacts fuel subsidies. In 2021, oil and gas importswere recorded at US$2.0 billion, around 12.5% of national imports. Efforts are needed to reduce the amount of imports. Raw materials that are easily found in Indonesia should be able to minimize the import process, which can increase prices. Therefore, using bagasse as bioethanol fuel can reduce dependence on fuel and the price of fuel subsidies, which are expected to reduce the price of fuel sold in the market.

The use of bagasse as a bioethanol fuel increases in octane value. This is because bioethanol has a higher octane number than gasoline. The octane rating is the maximum value or measure of the fuel when the engine is operating; a good octane rating is when the engine can work in a controlled manner. The higher the octane/RON value of the engine will be able to withstand the pressure in the combustion chamber before it burns out completely, which has an impact on the increase in power produced by the engine eh engine (Halim et al., 2023; Saragi & Purba, 2020).

3.3. Challenge Analysis

Apart from the existing advantages, the use of bioethanol has several challenges, such as further research is needed; advanced and expensive technology is required; and availability of raw materials. The government's plan for using bioethanol in fuel, namely BE5 blending, has not been implemented since 2020. This is undoubtedly due to unpreparedness to face the transition to renewable energy. There is still much research that must be done to achieve the use of bioethanol fuel. All parties must prepare a joint agenda to create concrete and maximum results.

The procedure for using bioethanol goes through several long processes; of course, it is not a small cost. Tools, raw materials, and land availability must be considered. In terms of cost, the production and distribution of bioethanol can be more expensive than traditional gasoline due to the complex production process and distribution lines. However, some governments are offering incentives and tax subsidies to encourage the use of ethanol.

When the raw materials used are in sufficient quantities and sustainably, they will decrease when they are continuously used on a large scale. Raw materials must continue to be produced and planted regularly. So, it is necessary to consider production costs and agricultural land. Materials that are difficult to collect or available only in limited quantities will be challenging to use as raw materials for large-scale industries (Aiman, 2014).

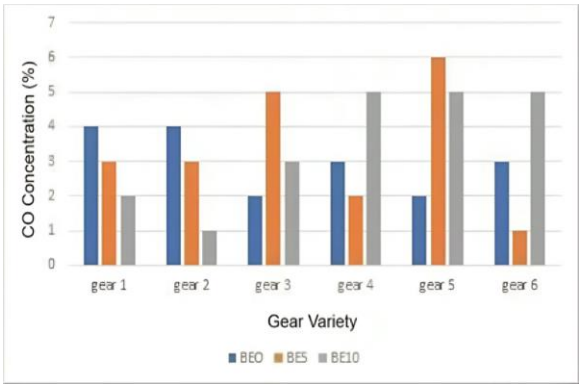

Figure 2. Flow chart of bioethanol production (Dyani & Rosariawari, 2021)

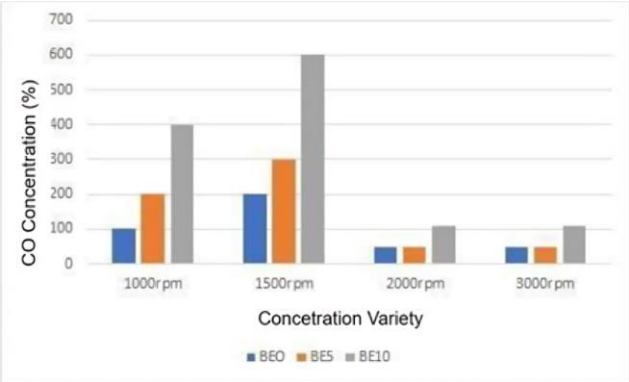

Figure 3. Graph Effect of RPM Concentration Variation on CO Concentration (Ismatullah & Muhaji, 2023)

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Apart from the existing challenges, the government's innovation and support can maximize bioethanol's potential use in reducing emissions and minimizing the challenges of bioethanol as a promising renewable energy source in the future. Regulations and policies on the use of bioethanol in Indonesia must be clear and genuinely implemented to maximize the impact. In addition, public awareness and cooperation are also needed to encourage this renewable energy transition.

4. Conclusion

This study shows that the government has supported bioethanol production in Indonesia, but the development is still not optimal. Further research is needed to overcome the problem of emission gases caused by transportation, study, and availability of materials on a large scale and industrial scale still needs to be carried out. The process of making bioethanol can be carried out in three stages: hydrolysis, fermentation, and distillation. The analysis results found several potential and challenges in using bagasse from bioethanol, namely, reducing carbon monoxide from combustion (19 - 25%), reducing fuel prices, and increasing octane value. Apart from the existing advantages, bioethanol has several challenges, namely the need for further research, sophisticated and expensive technology, and the availability of raw materials. In making innovations, full support from the government is needed, and in this research, it is hoped that future government projects can be implemented optimally.

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