

ANALYSIS OF ENVIRONMENTALLY FRIENDLY BIOGAS FROM CASSAVA PEEL WASTE WITH COW DUNG BIO-STARTER AND CASSAVA FERMENTATION WATER ADDITIVE

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Abstract

The development of renewable energy based on local agro-industry, especially through biogas from cassava peel waste, utilizes the great potential of industrial waste processing in South Sumatra which has not been optimized so far. South Sumatra is one of the centers of the cassava industry that produces large amounts of cassava peel waste, around 10-15% of the total weight of cassava processed. The high carbohydrate and fiber content in cassava peel makes it a source of organic material that supports conversion into biogas with methane content (CH_4) by 50–70%. The problem faced is how to optimize this waste as a biogas material, so as to reduce dependence on fossil fuels and reduce the burden of industrial waste. Therefore, the development of a method for processing cassava skin waste into biogas is carried out by utilizing cow dung as a bio-starter rich in microorganisms and cassava flour fermentation water as an additive to accelerate the anaerobic fermentation process, which can ultimately produce environmentally friendly energy. An experimental approach was applied in this study, including preparation of materials and arrangement of the mixture composition in several concentration variations. Fermentation was carried out in an anaerobic reactor with monitoring of the volume and composition of the gases produced, such as methane (CH_4), carbon dioxide (CO_2), hydrogen sulfide (H_2S), and nitrogen (N_2). Data analysis was conducted to evaluate the efficiency and quality of the biogas produced. Bio-starter from cow dung plays a role in breaking down organic matter into methane gas and CO_2 with the help of microorganisms, while fermented cassava flour water as a natural additive can increase gas production by 10–20%. The anaerobic fermentation process and the role of microorganisms in methane production are the main theoretical basis supporting this research. Initial results show that the combination of cassava peel waste, cow dung, and cassava flour fermentation water is able to produce biogas with high methane content and H_2S controlled, so that the gas quality remains safe. It is estimated that 1 kg of cassava peel can produce around 0.3–0.4 m³ of methane gas, which is enough to meet energy needs at the domestic and small industry levels. This finding indicates that the development of renewable energy from local agro-industrial waste has good prospects, especially with efforts to improve the quality and energy content of biogas. This technology is expected to provide significant benefits to society, the environment, and the green energy sector in the future, in addition to contributing to reducing CO₂ emissions up to 40% if applied as a substitute for LPG.

Keywords: Anaerobic fermentation, Biogas, Cassava peel waste, Cow dung bio-starter, Renewable energy.

INTRODUCTION

South Sumatra is the fifth-largest province producing cassava, with a total of 207,211 tons in 2023 according to the 2023 report from the. So far, cassava processing has only focused on utilizing the flesh, but the waste from cassava in the form of peels has not been further utilized. Cassava peel waste has high potential to be converted into biogas, a renewable energy source that can serve as an alternative to fossil fuels.

The introduction of renewable energy is important because the continued high use of fossil fuels causes environmental problems such as greenhouse gas emissions that accelerate climate change. According to the Dewan Energi Nasional (DEN), the highest energy mix in Indonesia in 2023 is still held by coal at 40.46%, petroleum at 30.18%, natural gas at 16.28%, and New Renewable Energy (EBT) at 13.09%. The utilization of this waste aligns with the principles of a circular economy, where waste is transformed into value-added products to support environmental and economic sustainability.

To improve the efficiency of biogas production, supporting materials are needed that can accelerate the fermentation process and enhance the quality of biogas. Cow dung has great potential as a bio-starter because it is rich in microorganisms that can decompose organic matter into methane gas (CH₄) and carbon dioxide (CO₂). Quoted from the official website of (grehenson, 2024) Gadjah Mada University, an average cow can produce 8 to 10 kilograms of manure per day, equivalent to 2.6–3.6 tons per year. This means that a farming area can produce more than 100 kilograms of waste per day.

Research shows that the addition of natural additives, such as cassava fermentation water, can increase gas production by 10–20% compared to without additives. (Ayu Saputri Saragih, 2024). The combination of cassava peel waste, cow dung, and fermented cassava flour water is expected to optimize biogas production with high methane content, while also reducing the environmental impact of organic waste.

LITERATURE REVIEW

Availability of Raw Materials

In the selection of raw materials for biogas production, essentially all organic waste, both liquid and solid, originating from livestock, agriculture, and even households can be used as raw materials for biogas. As one example, cassava peel waste, as we know, the cassava agricultural commodity in South Sumatra is the fifth largest producer of cassava in Indonesia. Therefore, it is very easy to obtain cassava peel waste as the main raw material for biogas production.

Biogas

Biogas is a mixture of gases formed from the decomposition of organic materials with the help of microorganisms through an anaerobic fermentation process (air-tight) that produces bio gas in the form of methane gas (CH₄) that can be managed. What must be considered during the biogas production process is the source of the raw materials or waste used because the quality and quantity of the resulting biogas will be greatly affected (Yahya *et al.*, 2018). This biogas product is an alternative product generated from organic waste decomposed by anaerobic microorganisms under airtight conditions, which also requires a starter in its production, where the decomposition process will eventually produce a flammable gas.

Fermentation

Fermentation is a biological conversion technique of complex substrates into simple compounds. The breakdown of complex components into simple compounds during fermentation involves the work of microorganisms. Fermentation based on the substrate used is classified into solid substrate fermentation and submerged fermentation. Solid state fermentation is a fermentation process using solid substrates. Solid state fermentation (SSF) has a high content or concentration

of solid substrates. So that complex compounds are present in large quantities. SSF has several advantages, including simpler media, lower costs, no need for aeration in aerobic fermentation, smaller fermentation space, and easy product harvesting (Subramaniam Ravichandran, 2012).

Bio-Starter

One example of a starter that is often used and easily obtained is EM4 (Effective Microorganisms), which contains microbes that are effective for use in organic materials and waste, household waste, factory waste, and so on. EM4 is capable of accelerating the degradation or fermentation of organic materials in the biogas formation process, referred to as a culture (starter), suppressing the growth of pathogenic microorganisms, and so on. Meanwhile, in the second use of the starter, which is cow dung. Essentially, the use of cow dung as a raw material for biogas contains sufficient microbial cultures or starters within it (Irawan Dwi, 2014). From these conditions, it indicates that cow dung itself contains microbes that have the ability to degrade organic waste to produce biogas.

Table 1. Results of previous literature review

Year of Publication	Researcher	Title	Method	Results or Conclusion
2020	Fransisca, Fierda., dkk	Efek Limbah Kulit singkong terhadap pembentukan biogas dari Kotoran sapi dan (studi kasus kampung injeman desa cibodas kecamatan pasir jambu, Bandung)	Eksperimental	The research results show that the M2 variation (100% cow dung) produced the highest methane gas, namely 46.02% on the 30th day and 37.86% on the 60th day. Other variations containing cassava peels did not produce methane due to factors such as low pH, small C/N ratio, high lignin content, and the presence of HCN in cassava peels that inhibit the growth of methanogenic bacteria. The fermentation process of M2 also showed the best organic material decomposition efficiency, evidenced by a significant reduction in COD and volatile solids.
2019	Pratiwi Irnanda., dkk	Produksi Biogas Dari Limbah Kotoran Sapi Dengan Digester Fixed Drum	Pendekatan Eksperimental dan Partisipatif	The biogas production process using a 600-liter fixed drum digester produces 1 m ³ of biogas per day, equivalent to 0.46 kg of LPG. To achieve this result, 5 cows are needed, producing 50 kg of manure per day. This biogas can be used as an alternative household fuel, replacing LPG, with an effective and environmentally friendly process.

2020	Anggari Virly Septira dan Prayitno	Studi Literatur Limbah Tapioka untuk Produksi Biogas : Pengolahan dan peranan Starter Substrat	Studi Literatur dan eksperimental	The conclusion of this study is that the batch method with a starter-substrate ratio of 4:10 produces optimal biogas production, amounting to 666 ml. Cow dung starter has proven effective due to its content of methanogenic bacteria, which supports the formation of methane gas. This method is suitable for laboratory scale with an optimal temperature setting of 30-35°C and a pH of 6.6-7.6. The use of the batch method also demonstrates high efficiency in processing tapioca flour liquid waste into environmentally friendly alternative energy.
2024	Fidela Wita., dkk.	Pemanfaata Kotoran Sapi Menjadi Biogas Sebagai Upaya Pengendalian Limbah Peternakan	Eksperimental	This research concludes that cow dung has great potential as a raw material for biogas, which simultaneously reduces environmental pollution caused by livestock waste. Anaerobic fermentation over 21 days produced methane gas, which began to form on the 14th day. The addition of straw increased the methane content and the quality of the biogas. Factors such as temperature, acidity level, material composition, and manure quality affect the production yield. This biogas becomes an environmentally friendly renewable energy alternative and an effective solution to livestock waste.
2021	Cruz lanny Andrade, etl	alorization of Cassava residues for biogas production in Brazil based on the circular economy : An updated and comprehensive review	Literatur Review	This research highlights the potential of cassava waste in Brazil as a raw material for biogas production within the framework of a circular economy. The anaerobic digestion (AD) process is capable of processing organic waste such as cassava peels, stems, leaves, and wastewater into biogas (primarily methane) and organic fertilizer. (digestate). The results show that anaerobic digestion (AD) not only reduces environmental pollution but also supports the production of renewable energy,

thereby providing economic, social, and ecological benefits, especially in agrarian regions such as northern and northeastern Brazil.

RESEARCH METHOD

This research is supported by data and information collected through the review of five previous literatures and journals on the Analysis of Environmentally Friendly Biogas Implementation from Waste, which can be seen in the table.

Of the five studies listed in Table 1, they illustrate the significant potential of organic waste for biogas production. However, there are several issues that need to be addressed, including the use of raw material combinations to enhance production efficiency from various raw materials, such as cow dung and cassava waste. There has not been much in-depth exploration of how combinations of raw materials with different characteristics can improve biogas production efficiency. For example, there has not yet been a systematic study evaluating the optimal proportion between raw materials with high carbon content and high nitrogen content (such as cow dung) to create the ideal ratio in the anaerobic fermentation process. To achieve better results, we as the authors need to:

1. Identifying combinations of raw materials that have the potential to increase methane gas production.
2. Exploring pretreatment or initial treatment of raw materials that are difficult to decompose, to enhance carbon availability for methanogenic bacteria.
3. Conducting trials with variations in the ratio of raw material mixtures, such as the comparison of straw and cow dung, to determine the most efficient combination.
4. Applying the best combination results on a pilot scale to evaluate the potential for field implementation.

RESULTS AND DISCUSSION

Cassava peel waste has great potential as a biogas raw material because it is rich in organic matter, such as starch and cellulose fibers. This content greatly supports the anaerobic fermentation process that produces methane (CH₄) as the main component of biogas. This is because this waste consists of various components that can serve as energy sources, including carbohydrates, fiber, and protein. On average, cassava peels contain about 60-70% carbohydrates, which serve as the main energy source for microorganisms in the fermentation process. Additionally, the fiber content in cassava peel waste acts as a raw material that can be decomposed by microbes, although this fiber is more difficult to break down. The moisture content in cassava peel waste also affects the fermentation process. The ideal moisture content for anaerobic fermentation is around 70-80%. Utilizing cassava peel waste as a raw material for biogas has various benefits. First, by processing this waste into biogas, the waste generated by the cassava processing industry can be minimized, thereby reducing its negative impact on the environment. In addition, the biogas produced can be used as an environmentally friendly alternative energy source, replacing the use of fossil fuels. The utilization of this waste also has the potential to raise awareness among the community and industry about the importance of waste management and environmental sustainability.

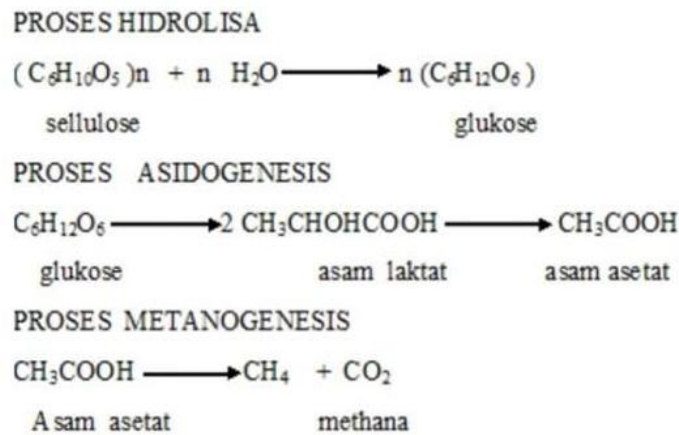


Figure 1. Stages of Fermentation Reaction

Source : (Renilaili & Pasmawati Yanti, 2016)

The anaerobic fermentation process is a key stage in the production of biogas from cassava peel waste. This fermentation involves microorganisms that decompose organic matter in anaerobic conditions, producing biogas consisting of methane (CH_4), carbon dioxide (CO_2), and a small amount of other gases. Cow dung, which is rich in methanogenic microorganisms, plays a crucial role in accelerating the anaerobic fermentation process that converts organic matter into biogas. According to research conducted by (Lehtomaki, 2017), the use of cow dung in a mixture of organic materials can increase methane production by about 30%, which demonstrates the important role of microorganisms in accelerating the conversion of organic materials into gas that can be used as an energy source. Cow dung contains various microorganisms such as methanogenic bacteria that are necessary for the methanogenesis process in anaerobic fermentation. Research by Kartikey Kumar Gupta (2016) shows that cow dung can increase the availability of microorganisms needed to accelerate the degradation of organic matter, which in turn increases the volume of methane produced. In the initial stage, these microorganisms digest the organic matter in cow dung and produce acetic acid, which is then converted into methane by other microbes in the anaerobic digestion system of cow dung. The combination of cow dung as a bio-starter and cassava fermentation water as a supporter can provide dual benefits in improving the quality and volume of the produced biogas. The research results by Lo Nilee Liew (2012) show that the use of these two materials in the anaerobic fermentation process enhances the stability of organic matter digestion and accelerates the methane production process, making it more efficient for use as renewable energy. Therefore, cow dung and cassava fermentation water as additives in biogas production can be an effective solution to improve the efficiency and quality of biogas.

CONCLUSION

1. Cassava peel waste has great potential as a raw material for renewable energy in the form of biogas.
2. The organic content in cassava peel and cassava fermentation water, such as starch, cellulose fiber, and carbohydrates, supports the anaerobic fermentation process to produce methane (CH_4), the main component of biogas.

3. The use of a bio-starter in the form of cow dung, which is rich in methanogenic microorganisms, has been proven to accelerate the anaerobic fermentation process and improve the quality of biogas.
4. The addition of cassava fermentation water as an additive can increase the efficiency of converting organic materials into methane gas by 10-20% compared to without additives.

The production of biogas not only provides an environmentally friendly fuel alternative but also supports a 40% reduction in carbon emissions, replacing LPG as the main energy source. Overall, biogas from cassava peel waste is an efficient, economical, and environmentally friendly solution to the problem of organic waste while also creating renewable energy.

ACKNOWLEDGEMENT

The author expresses the deepest gratitude to Mr. Arief Rahman, the supervising lecturer, for his patient guidance, profound direction, and moral support throughout the research and writing process of this scientific work. Thanks are also extended to UMKM Ubie Cuan Sejahtera, which has made an important contribution by providing research materials, greatly facilitating the smooth execution of this research. The dedication and cooperation provided greatly supported the achievement of optimal research results. The author also wishes to express gratitude to various other parties who have contributed, both directly and indirectly, by providing moral support, suggestions, and research facilities. May the assistance provided be a good deed, and may this written work benefit the readers and contribute to the development of knowledge in the field of renewable energy.

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