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Performance Analysis of Bio-batteries from Organic Waste for Alternative Electric Energy

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Abstract

Background of study: Biobatteries are an innovative form of renewable energy technology that utilize organic materials to produce electricity through electrochemical reactions. Organic waste such as banana and pineapple peels contains natural electrolytes, making them potential sustainable and eco-friendly energy sources.
Aims and scope of paper: This study aims to evaluate the performance of simple biobatteries using banana and pineapple peels as electrolyte materials. The research focuses on measuring voltage and current generation over seven days and assessing the stability and durability of each type of organic waste.
Methods: Biobatteries were assembled using zinc (Zn) electrodes as the anode and carbon rods as the cathode. The peels were ground into a paste and used as the electrolyte. Daily measurements of voltage and current were taken for seven consecutive days to analyze performance trends.
Result: Test results showed that both types of biobatteries were capable of producing sufficient voltage and current to power simple electronic devices such as small LEDs, wall clocks, and basic household appliances. However, biobattery performance decreased over time due to water evaporation, degradation of active compounds, and environmental influences such as temperature and humidity. Overall, banana peels performed more consistently than pineapple peels.
Conclusion: This research demonstrates that organic waste can serve as a viable material for renewable energy generation. Biobatteries made from fruit peels not only help reduce waste but also have potential for educational use and community energy initiatives.

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INTRODUCTION

The global demand for electrical energy continues to rise alongside technological advancements and the growing human population. However, most electricity is still dependent on fossil energy sources such as coal, petroleum, and natural gas. These resources are non-renewable and produce high carbon emissions, which contribute significantly to global warming and climate change (Nusantoro & Awaludin, 2020). Therefore, it is essential to seek alternative energy sources that are environmentally friendly, renewable, and both accessible and affordable.

One of the emerging innovations in the field of alternative energy is the bio-battery. A bio-battery is an electrochemical cell that utilizes organic materials to generate electricity. The working principle of a bio-battery is based on redox reactions occurring between two electrodes embedded in an organic substance that serves as an electrolyte. When metals such as zinc (Zn) and carbon (C) are used as electrodes, they react with the chemical compounds in the organic material to produce electric current (Andini, 2024). This simple concept enables the utilization of organic waste to generate alternative energy that previously went untapped.

As one of the provinces with the largest production of bananas and pineapples in Indonesia, the Central Statistics Agency (BPS) reported that Lampung was able to produce 1,322,020 tons of bananas in 2023, and 722,847 tons of pineapples in 2023. Most of the bananas and pineapples are processed into food products, resulting in abundant waste from banana peels and pineapple skins. Banana peels contain acetic acid, which is a type of electrolyte that can generate electricity. Banana peels have the potential to be processed into electrodes through chemical activity to be used as a material for producing electrical energy (Tadesse et al., 2023). Meanwhile, pineapple skins contain ascorbic acid, which is also a type of electrolyte (Fitrya et al., 2023). This electrolyte plays a role in generating ions that can move and produce electricity (Alawiyah et al., 2023). In addition, the soft and moist skin texture helps electrolytes function effectively as a natural electronic medium.

The development of bio-batteries has been researched by Several international studies have explored the viability of organic materials for bio-battery applications. Roselle Angela G. Torres et al. (2023), demonstrated that microbial fuel cells utilizing different banana peel varieties Lakatan, Latundan, and Saba, achieved up to 0.276 V and 1.121 mA, with the Saba variety showing the most stable performance. Rojas-Flores et al. (2022), successfully generated over 1 V and 3.7 mA using banana waste in a zinc–copper microbial fuel cell, identifying multiple bacterial species contributing to bioelectricity. Another study from Sitanggang et al. (2021), also showed that pineapple peel paste was able to generate an electric voltage of 2.4 volts and an electric current of 0.12 mA, which was sufficient to power an LED light for 14 hours.

This study focuses on utilizing banana peels and pineapple peels as active materials for bio-battery development. These two types of fruit peels were selected due to their high availability, ease of acquisition, and considerable electrochemical potential. The experimental tests were conducted using untreated banana and pineapple peel waste, without fermentation or added chemicals, thereby maintaining their natural properties. Zinc electrodes were used as the anode due to their high reduction potential, while carbon electrodes served as the cathode. The performance of the bio-batteries made from banana and pineapple peels was observed over a continuous seven-day testing period. The testing involved daily measurements of voltage (in volts) and electric current (in amperes or milliamperes) at approximately the same time each day. This was done to analyze fluctuations in the energy produced and to evaluate the stability and durability of each type of bio-battery in generating electricity.

Monitoring the voltage and current over a week aimed to identify trends in power reduction, which are typically caused by the evaporation of electrolytic fluid, the depletion of active compounds in the fruit peels, or environmental changes such as temperature and humidity (Sulistyowati et al.). This data is essential for evaluating the long-term durability of the bio-batteries. Additionally, the tests provided insights into the efficiency of each organic material used. From the daily measurements, it is expected to determine which between banana and pineapple peels performs better in generating electrical energy. This becomes a crucial consideration in selecting the most suitable raw material for further development, not only based on voltage and current output but also in terms of performance stability and sustainability as an alternative energy source.

This research is expected to contribute not only to the development of low-cost, environmentally friendly renewable energy technologies but also to serve as a learning medium in the context of science education in schools. Bio-batteries made from fruit peel waste can be a concrete example of how scientific concepts such as redox reactions, conductivity, and electricity can be applied in real-life contexts, while simultaneously fostering awareness about waste management and sustainable innovation. However, although there have been numerous studies on alternative energy derived from organic waste, only a few have specifically examined the use of banana and pineapple peels as the main materials in the development of simple bio-batteries. Most previous studies have focused on complex systems such as microbial fuel cells, leaving a gap in research that evaluates the performance particularly voltage and current output of fruit peel based bio-batteries in a practical and measurable way. Furthermore, little research has directly linked this type of innovation with classroom implementation, particularly as contextual, project-based learning tools in science education. Based on these gaps, this study aims to examine the electrical performance of bio-batteries made from banana and pineapple peels over a seven-day observation period, compare the stability and effectiveness of the two types of fruit waste in generating electricity, and explore their potential use as contextual learning media in science education to enhance students' energy literacy and environmental awareness.

METHOD

This study employed a pre-experimental research design to evaluate the electrical performance of bio-batteries made from banana and pineapple peels, focusing on voltage and current output over a seven-day observation period.

1. Biobattery Preparation Stage
   This research used banana peel and pineapple peel waste as the main materials. These two types of waste were processed separately without the addition of any chemicals. The processing process was carried out by grinding the banana peel and pineapple peel using a blender until a homogeneous paste was obtained. The resulting bio-battery paste was then transferred to a special storage container for use in the next testing phase. The equipment used in this research included a blender for the grinding process, a storage container for the bio-battery paste, and copper (Cu) and zinc (Zn) metal plates that functioned as electrodes. In addition, carbon rods were also used as a supporting component in the bio-battery system.

2. Electrical Performance and Durability Test
   The electrical and durability tests were conducted to determine the voltage and current output produced by the bio-batteries, as well as the duration of their energy output. The electrical test was carried out using Cu-Zn metal plates as the anode and carbon rods as the cathode. These electrodes were connected to a digital multimeter using alligator clip wires. Measurements of the voltage and current produced by the bio-batteries were then taken and recorded. Voltage and current measurements are carried out without applying a load to the circuit. This testing was conducted over a period of seven consecutive days to evaluate the endurance of the bio-batteries throughout one week.

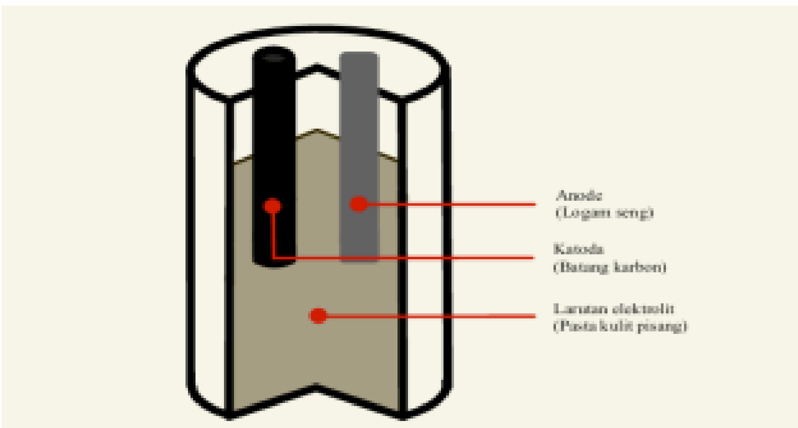

Figure 1. Design Of Biobattery Product Plans

3. Data Analysis Stage
   The data collected in this study consisted of voltage and current measurements produced by the biobattery. These measurements were carried out manually using a digital multimeter and

recorded daily for seven consecutive days. Each measurement was carried out at approximately the same time each day to maintain consistency in environmental conditions such as temperature and humidity, which can affect the results. After being collected, the data were analyzed using a descriptive quantitative method. This analysis began by calculating the average (mean) value of the daily voltage and current to determine the general performance of the biobattery during the observation period. Furthermore, a daily fluctuation analysis was carried out by calculating the difference in values between one day and the next, both in the form of absolute values and percentage changes, to assess the stability and tendency of energy output to rise and fall. To assess the level of data variation, the standard deviation was also calculated, which shows how much the values are spread from the average. A low standard deviation value indicates stable biobattery performance, while a high value indicates significant variation between days. In addition, the coefficient of variation was used to provide an overview of the level of stability relative to the average value. This data analysis aims to evaluate the stability and durability of the biobattery during the test period and to provide insight into the effectiveness of organic waste as a raw material for alternative energy generation. These findings are expected to be the basis for the development of more efficient and sustainable innovations in the future.

RESULTS AND DISCUSSION

The testing was conducted over a period of seven consecutive days to observe the performance of banana peel and pineapple peel bio-batteries in generating voltage and electric current. Measurements were taken using a digital multimeter. The observation results are presented in Table 1 below:

Table 1. Voltage and Current Measurement Results of Bio-batteries Over 7 Days

Day	Waste	Voltage (v)	Current (A)
1	Banana Peel	0.96	0.43
	Pineapple Peel	0.94	0.19
2	Banana Peel	0.88	0.26
	Pineapple Peel	0.88	0.18
3	Banana Peel	0.88	0.24
	Pineapple Peel	0.74	0.19
4	Banana Peel	0.95	0.21
	Pineapple Peel	0.63	0.13
5	Banana Peel	0.88	0.37
	Pineapple Peel	0.70	0.22
6	Banana Peel	0.70	0.28
	Pineapple Peel	0.67	0.21
7	Banana Peel	0.64	0.18
	Pineapple Peel	0.57	0.22

Based on the measurements taken over seven consecutive days, it was found that the average voltage produced by the banana peel bio-battery was 0.84 volts, while the pineapple peel bio-battery produced an average voltage of 0.73 volts. Furthermore, the average current generated by the banana peel bio-battery was 0.28 amperes, whereas the pineapple peel bio-battery produced an average current of 0.19 amperes. This difference indicates that banana peels have better conductivity than pineapple peels, possibly due to the more stable electrolyte content and support for a more effective ion transfer process. This shows that carbon from banana peels has a content that supports ion diffusion and higher electrical conductivity compared to carbon from pineapple residue (Tadesse et al., 2024). Based on these results, it is proven that biobatteries have the ability to generate electrical energy even when made from organic waste materials such as banana and pineapple peels. This shows that the initial performance of the biobattery is relatively stable in the context of short-term use. This finding is in accordance with research conducted by Salawali & Lestari (2024), which showed that banana peel-based bio-batteries produced voltages ranging from 0.85 to 0.95 volts and currents between 1.5 mA and 2.5 mA, with an operational lifespan of 14 to 16 hours. Banana peels are considered effective materials for bio-batteries due to their sufficient electrolyte content, which facilitates good electrical conductivity. Additionally, research by Welly et al. (2024), supports similar conclusions, demonstrating that pineapple peel-based bio-batteries are also capable of generating voltage and current. Variations in electrolyte composition and the type of electrodes used significantly affect the output values of voltage and current. Variations in electrolyte composition and the type of electrode used significantly affect the output voltage and current values. This indicates that banana peels tend to be more stable and efficient than pineapple peels in the context of short-term electrical energy production using organic waste. In accordance with the results of research conducted by Ramadhan et al. (2022), which explored the use of pineapple peel filtrate as an electrolyte in biobatteries, which was combined with polyvinyl alcohol polymers and glycerol to prevent crystallization. Under optimal conditions 0.75:1 ratio of filtrate: polymer and addition of 3 g of glycerol, the biobattery showed an increase in voltage, current, and electrical power. So it can be proven that the electrolyte composition greatly affects the output efficiency.

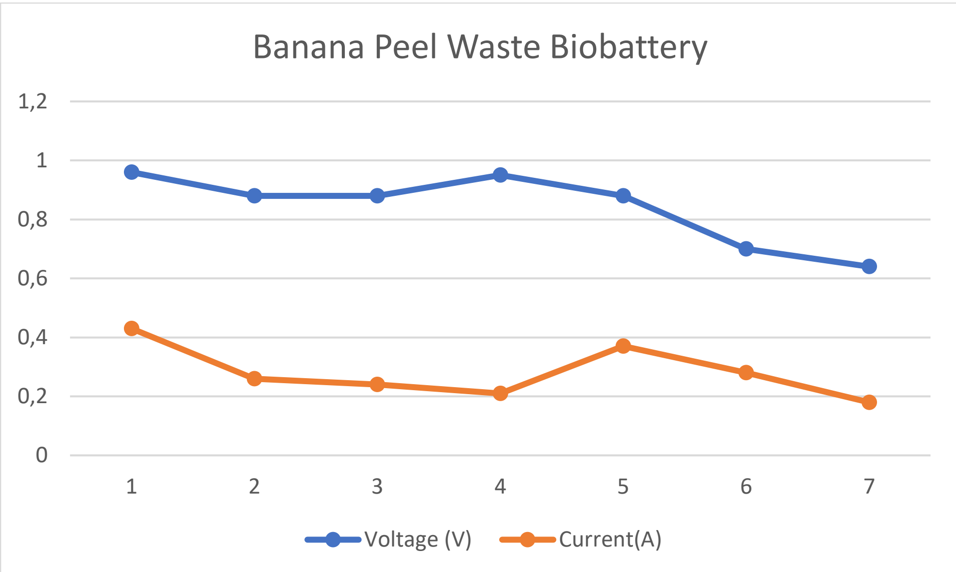

Figure 2. Graph of Voltage and Current Measurement Results of Banana Peel Bio-Battery

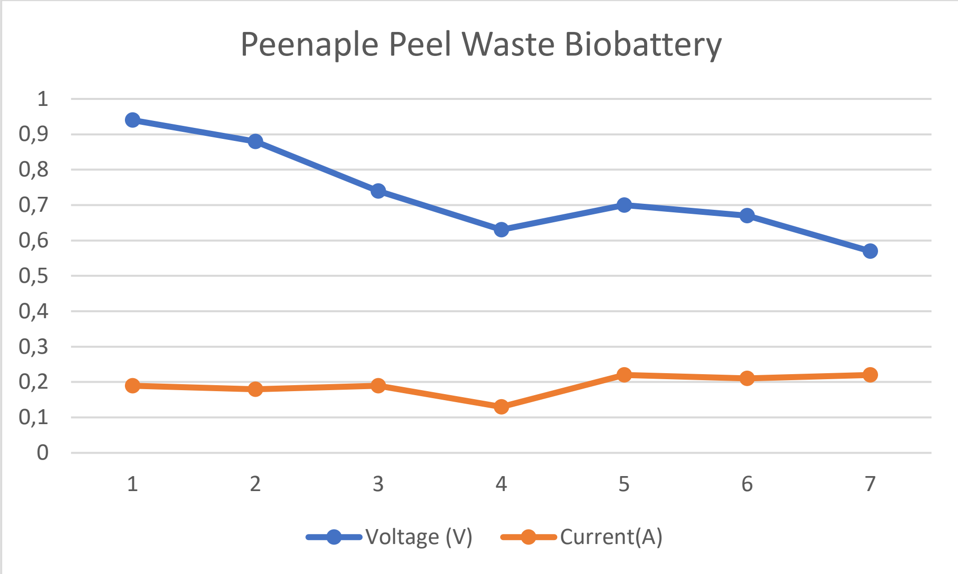

Figure 3. Graph of Voltage and Current Measurement Results of Pineapple Peel Bio-Battery

During the observation period, fluctuations in voltage and current values were recorded from day to day. On day 1, the highest voltage output was recorded for both banana peel and pineapple peel bio-batteries, which were 0.96 volts and 0.94 volts, respectively. In contrast, the lowest voltage values were recorded on day 7, with 0.64 volts for the banana peel bio-battery and 0.57 volts for the pineapple peel bio-battery. These fluctuations were likely caused by a decrease in the concentration of active compounds, evaporation of the electrolyte fluid, or changes in environmental temperature and humidity that affect the bio-battery's electrochemical reactions. This indicates that environmental factors influence the performance of the bio-battery, such as ambient temperature and the duration of the chemical reactions The performance of biobatteries from organic waste such as banana peels and pineapple skins tends to decline after the oxidation process of the organic materials is completed (Yaqoob et al., 2023). This is in line with the findings of Welly et al. (2024), who stated that electrolyte evaporation and oxidation significantly influence the performance of bio-batteries. This is also in line with research conducted by Rojas-Flores et al., (2022), which shows a decrease in the performance of the biobattery from pineapple skin used which is influenced by the condition of the microbes found on the pineapple skin and the temperature conditions of the environment where the biobattery from pineapple skin is stored.

In general, the performance of the bio-batteries showed a declining trend over the seven-day observation period. This is evidenced by a gradual decrease in the voltage and current values starting from day 2 through day 7. This is in line with research Tabish et al., (2023) which shows the pattern of voltage drop experienced by the biobattery. The pattern indicates that the chemical reactions within the bio-batteries gradually lose efficiency over time, a common characteristic of organic waste-based energy sources. This finding supports the study by Fitrya et al. (2023), which revealed that the number of operational days influences the reduction in voltage and current values, thereby indicating a decrease in bio-battery performance within a one-week period. A study from Adekunle et al., (2019) also showed a decrease in electrical voltage from 367 mV to 145 mV during the observation period, which occurred due to a decline in chemical reactions. This decrease occurred gradually over the operational days of the bio-battery.

The efficiency of the bio-batteries can be evaluated by their ability to maintain voltage and current output over the seven-day period. Although a decline was observed on several days, the bio-batteries consistently generated electricity until day 7. These results demonstrate that bio-batteries made from organic waste such as banana and pineapple peels have potential as environmentally friendly alternative energy sources. With their ability to consistently produce electricity over a limited duration, bio-batteries can be utilized for small-scale applications, particularly in educational contexts or the development of simple and sustainable technologies. Their durability is sufficient for basic applications, such as powering small household devices like LEDs, wall clocks, and others. Additionally, they can serve as educational tools in physics lessons on alternative energy, organic waste processing, and electrical concepts such as Ohm's Law (Fitrawati & Saehana, 2021). This approach is highly suitable for physics or science learning in schools because it integrates the concept of electricity in physics with principles of biology and environmental chemistry (Tagliaferri et al., 2024). This can be used as a STEM learning medium for high school students, which practically facilitates students to learn about the concept of alternative energy, organic waste processing, and electrical principles such as Ohm's law and electrochemical reactions. Thus, biobatteries can be contextual and applicable learning aids, while increasing awareness of renewable energy and environmental sustainability (Tan & Lee, 2022 ; Dewan & Lewandowski, 2010)

This study, however, has several limitations. These include the relatively short observation period of only seven days, the use of manual measuring instruments that may have limited accuracy, and the lack of controlled environmental variables. Moreover, only two types of organic waste were used as the primary materials for the bio-batteries. Despite these limitations, this research contributes to the utilization of organic waste as an environmentally friendly energy source. Furthermore, it can serve as a foundational reference for developing educational projects that integrate renewable energy concepts and waste management into science learning. The implications of this study also highlight the importance of further exploration of simple bio-battery-based technologies. The simplicity of the design encourages further innovation at the grassroots level, including by students and local communities, fostering technology democratization and contextual science education (Rojas-Flores et al., 2022). In the context of science education, the practice of creating bio-batteries from fruit waste provides students with hands-on experience in understanding the relationship between scientific concepts and their impact on the real environment. Such learning not only strengthens the understanding of electrochemistry and alternative energy concepts but also fosters environmental awareness, as explained by Tan & Lee (2022), who found that project-based activities related to bioenergy can significantly improve students' energy literacy and ecological awareness. The utilization of organic waste, such as banana and pineapple peels, for biobattery production not only supports contextual learning practices but also provides a positive contribution to the environment. According to a study by Perumal (2024), the use of fruit and vegetable waste in bioenergy production, including biobatteries, promotes the reduction of greenhouse gas emissions, minimizes waste accumulation, and improves resource use efficiency.

Future research is recommended to expand the variety of organic waste materials used in order to compare their efficiency. It is also suggested that observations be conducted over a longer period using sensor-based measuring tools to obtain more accurate and real-time data. Moreover, the development of series or parallel circuit designs is essential to better understand the potential for increasing the power output of bio-batteries.

CONCLUSION

Based on the results of voltage and current measurements and data analysis conducted over seven days, it can be concluded that bio-batteries made from organic waste—specifically banana and pineapple peels—are capable of generating electrical energy in limited amounts, yet sufficient for simple applications. The voltage and current outputs showed fluctuations from day to day, with a general trend of gradual decline over time. However, the bio-batteries consistently demonstrated the ability to generate electricity up to the final day of observation, indicating potential as an environmentally friendly and sustainable alternative energy source. These findings suggest that bio-batteries can be further developed, both in the context of renewable energy research and as educational tools. They hold promise for raising awareness about the utilization of organic waste and for teaching concepts related to alternative energy and electricity, such as Ohm's Law.

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AUTHOR CONTRIBUTION STATEMENT

MA was responsible for research planning, data collection, and writing the main manuscript. AF assisted in data analysis, composed the discussion section, and contributed to revising the manuscript. KH facilitated and guided the direction of the research and provided conceptual input in the writing of the article manuscript.

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