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Electric Generation Capacities of Three Varieties of Banana Peel Using Microbial Fuel Cell

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Abstract Agricultural waste can be a viable energy source to generate electricity through a microbial fuel cell. Subsequently, banana peels are a widely available agricultural waste that can be utilized to generate electricity through a microbial fuel cell. In this study, an innovative method was adopted to generate bioelectricity from the three varieties of banana peels by using a microbial fuel cell (MFC). This study aimed to comparatively evaluate the electric generation capacities and dissipation rates of the three varieties of banana peels using microbial fuel cells. The microbial fuel cell's electric generation capacities and dissipation rates were measured for seven days. One-way ANOVA was utilized to ascertain the significant difference in the electric generation capacities and dissipation rates of the three varieties of banana peels. Results showed that all banana peels produced electricity in slightly different amounts. On average, Lakatan has a voltage and current of 113.841 mV and 134.543 μA, Latundan has a voltage and current of 152.521 mV and 145.43 μA, Saba has a voltage and current of 247.8229 mV and 395.986 μA. Overall, ANOVA revealed that there is a significant difference in the electric generation capacities in terms of voltage and current. However, there is no significant difference in the dissipation rates of the three varieties of banana peels. The study concludes that the Saba peels could be a potential feedstock for MFCs due to their high electric generation capacity and low dissipation rate compared to other varieties of banana peels. However, further studies are needed to optimize the MFC parameters for electricity generation, such as varying set-up sizes of the chambers, salt bridges, and chemical contents of the substrate.

Keywords: *agricultural waste, banana peel waste, bioelectricity, dissipation rate, electric generation capacity, microbial fuel cell, microorganism, substrate*

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1. Introduction

Electricity plays a vital role in daily life. It is used to power home appliances that will provide convenience and ease of use like no other [1]. The uses of electricity are seen in everyday activities such as those in communications, business, transportation, education, and domestic life [2]. Access to electricity has improved in the Philippines. However, the country still faces an energy problem. The number of Filipinos without access to power or encountering brownouts is close to 30 % [3].

Moreover, according to energy officials, rotating brownouts will affect 1.3 million households this year because of the high fuel cost. Most affected people live in rural or "off-grid" locations [4]. Brownouts are unintentional or intentional drops in an electrical grid's voltage. This reduction in electrical power occurs when there is increased use of electricity and too much demand on the system. Brownouts are common occurrences in the Philippines and can severely impact the lives of the people and those who rely on a rural-based economy [5].

Numerous challenges to energy production and distribution are prevalent in the Philippines. Moreover, rapid population growth and industrialization will lead to a higher demand for electricity and prices that are among the highest in Southeast Asia. The Philippine government plans to use a combination of fossil fuels and renewable energy sources to achieve energy independence for the country by 2030. By 2040, an extra 43 GW of electrical capacity will be needed, and the nation needs to catch up in creating answers [6]. Indeed, the country needs to exhaust all possible means of meeting these challenges. One way it can help solve brownouts and other energy problems is by providing a more stable and consistent energy source that does not rely on traditional power grids. By creating bioelectricity, communities can become more self-sufficient and less vulnerable to power outages caused by brownouts. In addition, since bioelectricity is a clean energy source, it can help reduce carbon emissions and mitigate the impacts of climate change.

Agricultural waste is a viable and potential energy source. It is now widely used across the world to generate electricity. Through technical innovation, agricultural waste can be transformed into a supplemental source of electricity to power vital household equipment [7]. Bioelectricity production utilizing Microbial Fuel Cells (MFC) is an alternative, pollution-free, and efficient process that generates green and renewable energy. Microbial fuel cells absorb energy from organic materials like agricultural wastes such as rice hulls, oil palm residues, sugar cane bagasse, and fruit peels during microbial metabolism in the form of bioelectricity. This electricity-harvesting approach can diversify the energy source, which could lessen reliance on imported fuels. [8]. Moreover, the Philippines is one of the world's top 10 producers, exporting an estimated 3.5 million tons of bananas annually. In a 2018 report, the majority, or 84%, of the total banana production in the Philippines was grown in Mindanao regions [9-10]. Since the banana fruit generates a large quantity worldwide, particularly in the Philippines, exploring its possible uses in electricity generation is exciting and vital.

Although several research studies focus on generating bioelectricity from banana peels through a microbial fuel cell, no research studies compare the electric generation capacities of the different varieties of banana peels. So, this study aimed to evaluate the electric generation capacities of the three varieties of banana peels. It also aimed to determine if there is a significant difference in the voltages, currents, and dissipation rates generated from the peel waste of three different types of bananas.

2. Methodology

2.1. Preparation of Banana Sludge

Three types of banana peel were used in the experiment, Latundan (*Musa acuminate x M. balbisiana* (AAB Group) 'Silk'), Lakatan (*Musa acuminate Colla*), and Saba (*Musa acuminate x balbisiana*). Then, 1000 grams of each variety of banana peel was chopped and mixed with water using a blender, creating a slurry mixture. The exact amount of mixture for every banana was placed inside the containers. Lastly, the yellowish mixture turns black, and this coloration change from yellow to black indicates that the banana sludge is ready for use.

2.2. Preparation of Experimental Set-up

To make a four-chamber series of microbial fuel cells, make a hole in the lids of the containers for the positive and negative wires to go through and create other holes on the lid of the cathodic chamber for air to pass through. Then, utilize four circular plastic containers and make a hole on one side of the containers; the hole should be large enough for the PVC pipe to fit in. These chambers will represent the anodic and cathodic chambers connected through a seven (7) inches long PVC pipe acting as the proton exchange membrane or salt bridge. Moreover, the copper wire was connected inside the folded aluminum mesh with the wire coming from one end [11].

To make the salt bridge (proton exchange membrane), 75 grams of salt was dissolved in 1L water, and 100 grams of unsweetened gelatin powder was added to solidify. Then, heat the solution for fifteen minutes and put it in the small PVC pipe. Place the banana sludge in the anodic chamber while tap water is in the cathodic chamber of the microbial fuel cell. Lastly, to make a series microbial fuel cell, connect the wires of the two cathodic chambers and the wires of the two anodic chambers

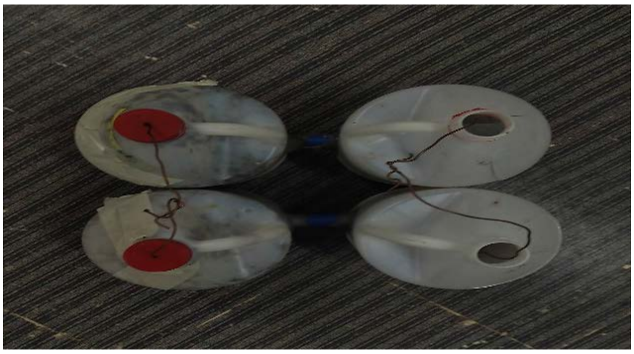

Figure 1. Actual Structure of the Series Microbial Fuel Cell

2.3. Data Gathering

The electric generation capacities of the three varieties of banana peels, specifically the voltage and current, were measured using a digital multimeter. The set-ups are measured ten times every ten seconds to ensure their reliability. Place the red probe of the multimeter into the copper wire of the cathodic chamber (water) while the black probe for the anodic chamber (banana sludge). Then, utilize alligator clips to connect the two wires temporarily. The microbial fuel cells were monitored for seven days at 24-hour hours.

The voltage dissipation rates were calculated for seven days with a 24-hour interval and computed using the equation 1.

$$DR = \frac{\Delta V}{\Delta t} \quad (1)$$

DR = Dissipation Rate
ΔV = Change in voltage
Δt = Change in time.

2.4. Statistical Tool

Data from this study were analyzed using mean, standard deviation, and One-Way ANOVA.

3. Results and Discussion

Table 1. Descriptive Statistics of the Generated Voltages of the Three Varieties of Banana Peels

Variety of Banana Peel	Min (mV)	Max (mV)	Mean and SD of Voltage (mV)
Lakatan	66	169.2	113.841 ± 39.429
Latundan	83	226	152.521 ± 41.612
Saba	219	276	247.823 ± 10.018

Table 1 shows the mean average generated voltage of the three varieties of banana peel wastes: Lakatan, Latundan, and Saba, using microbial fuel cells. During testing, different voltages were generated, attaining the highest generation of 276 mV from Saba and the lowest generation of 66 mV from Lakatan. As the table shows, Saba has a higher mean of 247.823 mV generation and a lower standard deviation than Lakatan and Latundan. The experiment results demonstrate that Saba has the highest electric generation capacity of voltage among the three varieties of banana peel waste. The generated voltages among the three varieties of banana peels using microbial fuel cells maybe be due to the anaerobic respiration of the microbes present in the banana peel waste and the microbial fuel device use. It stated that microorganisms or microbes may be used as an alternative power source via microbial fuel cells [12]. Additionally, a study revealed that banana peel waste successfully generated electricity with an average of 1.01 ± 0.017 V via microbial fuel cell [13].

Table 2. Descriptive Statistics of the Generated Currents of the Three Varieties of Banana Peels

Variety of Banana Peel	Min (μA)	Max (μA)	Mean and SD of Current (μA)
Lakatan	68	205	134.54 ± 43.502
Latundan	102	271	145.43 ± 38.067
Saba	204	1121	395.99 ± 166.757

Table 2 shows the mean average and standard deviation of generated current among the three varieties of banana peel wastes: Lakatan, Latundan, and Saba, using microbial fuel cells. Different currents were generated during testing, attaining the highest generation of 1121 μA from Saba and the lowest generation of 68 μA from Lakatan. As the table shows, Saba has a higher mean of 395.99 μA generation and a lower standard deviation than Lakatan and Latundan. The experiment results demonstrate that Saba has the highest electric generation capacity of current among the three varieties of banana peel waste. The generated current among the three varieties of banana peel waste using microbial fuel cells may be due to the nutrients in banana peel waste. The study reported that banana has a nutrient containing glucose, an alternative product that may be turned into biofuel resources [14]. Furthermore, a study on the deconstruction of banana peel for carbohydrate fractionation showed that 9.9 g of xylose, 0.5 g of XOS, and 8.2 g of glucose were obtained from 100 g of raw banana peels [15]. Moreover, glucose is a favorite dietary component of microbes since it is a simple sugar derived from the food that microbes consume [16].

Table 3. Descriptive Statistics of the Dissipation Rates

Variety of Banana Peel	Min (mV)	Max (mV)	Mean and SD of Voltage (mV)
Lakatan	-3.85	1.833	-0.641 ± 1.790
Latundan	-3.042	3.583	-0.699 ± 0.204
Saba	-1.208	1.208	-0.192 ± 0.121

Table 3 shows the mean and standard deviation of Lakatan, Latundan, and Saba voltage dissipation rates. The data shows that Lakatan increased by 1.833 mV on the fourth day but dropped by 3.85 mV on the fifth day. For Latundan, it dropped by 3.042 mV on the second day but increased by 3.583 mV on the sixth day. For Saba, it dropped 1.208 mV on the fourth day but increased 1.208 mV on the fifth day. This also shows that Saba has the lowest voltage drop of 0.192 mV while Latundan has the highest drop of 0.699 mV. This may be due to the growth of bacteria and the flow rate of the set-up. According to a study, bacteria produce electricity through conductive nanowires and other cell organelles [17]. A recent study also mentioned that microbial fuel cell has a low growth rate of microbes and become the materials in toxic [18]. Moreover, the substrate's depletion of glucose and mannitol can lead to a lower growth rate of bacteria, resulting in a higher voltage drop [13].

Table 4. One-way ANOVA Table Examining the Difference in the Voltage Generated by the Three Varieties of Banana Peels

Source	SS	Df	MS	F	p-value
Treatment (between groups)	665750.12	2	332875.06	325.54	<.0001
Error	211663.03	207	1022.52		
Total	877413.15	209			

*Significant at 0.05 level.

The critical value of F at $\alpha = 0.05$ and degrees of freedom $v_1 = 2$ and $v_2 = 207$ is 3, whereas the computed F value is 325.54. This implies that there is statistical evidence to reject the null hypothesis and conclude that there is a significant difference in the voltage generated by the three varieties of banana peels. Also, the p-value of <.0001 is less than $\alpha = 0.05$, suggesting that the null hypothesis should be rejected. Post hoc test, specifically Tukey's HSD test, was performed, and it revealed that all groups of banana peels are significantly different. This may be due to the high nutritional content of Saba compared to other varieties. The study indicated that Saba has the highest content of nutrients because it has the deepest roots among other banana plants, allowing it to absorb more nutrients from the soil. It also contains high amounts of resistant starch, up to 68.1%, higher than other tropical banana cultivars, and pectin and potassium [18]. Furthermore, the study revealed that bacterial growth media and bacterial biomass density were increased due to high nutrient and strength electrolytes [19].

Table 5. One-way ANOVA Table Examining the Difference in the Current Generated by the Three Varieties of Banana Peels

Source	SS	Df	MS	F	p-value
Treatment (between groups)	3063453.15	2	1531726.57	118.61	<.0001
Error	2673252.12	207	12914.26		
Total	5736705.28	209			

*Significant at 0.05 level.

The critical value of F at $\alpha = 0.05$ and degrees of freedom $v_1 = 2$ and $v_2 = 207$ is 3, whereas the computed F value is 118.61. This implies that there is statistical evidence to reject the null hypothesis and conclude that there is a significant difference in the current generated by the three varieties of banana peels. Also, the p-value of <.0001 is less than $\alpha = 0.05$, suggesting that the null hypothesis should be rejected. Post hoc test, specifically Tukey's HSD test, was performed, and it revealed that group 1 (Lakatan) and group 2 (Latundan) are significantly different from group 3 (Saba). This may be due to the high nutritional content of Saba. It indicated that Saba has the highest content of nutrients because it has the deepest roots among other banana plants, allowing it to absorb more nutrients from the soil. It also contains high amounts of resistant starch, up to 68.1%, higher than other tropical banana cultivars, and pectin and potassium [19]. Moreover, the substrate is one of the critical components influencing electrical energy generation with MFC. Organic and nutrient-rich substrates typically have high current densities, power densities, and Faraday efficiency [21].

Table 6. One-way ANOVA Table Examining the Difference in the Dissipation Rates of the Voltage Generated by the Three Varieties of Banana Peels

Source	SS	Df	MS	F	p-value
Treatment (between groups)	8.867169	2	4.433584	1.74	0.178509
Error	450.841602	177	2.547128		
Total	459.708771	179			

*Significant at 0.05 level.

The critical value of F at α = 0.05 and degrees of freedom $v_1 = 2$ and $v_2 = 177$ is 3, whereas the computed F value is 1.74. This implies that there is statistical evidence to accept the null hypothesis and conclude that there is no significant difference in the voltage dissipation rates of the three varieties of banana peels. Also, the p-value of 0.178509 is not less than α = 0.05, suggesting that the null hypothesis should be rejected. This could have been due to the same structure of the microbial fuel cell used in each variety of banana peels. A recent study stated that several factors are responsible for the electrical output of the MFC, such as the design of the MFC, electrode materials, pure culture or mixed culture inoculum, proton exchange membrane, and operation conditions (pH and temperature). Moreover, the salt bridge also helped transport protons from the cathode to the anode to generate higher electricity [21].

4. Conclusions

The electric generation capacities of three varieties of banana peels: Lakatan, Latundan, and Saba, using a microbial fuel, were proven to produce voltage and current. The highest generated voltage and current were Saba, with 276 mV and 1121 µA. This study concludes that Saba is more capable and efficient in generating electricity compared to other varieties.

The lowest drop rate of voltage is Saba, with 1.208 mV. On the other hand, the highest drop rate of voltage is Latundan, with 3.583 mV. This study concludes that Saba has the lowest voltage drop rate and has the most stable voltage generated among the three varieties of banana peel wastes.

Using the One-way ANOVA test, the three varieties of banana peels show significant differences in terms of voltage and current. The results showed that all groups of banana peels have significantly different voltages. This concludes that the Lakatan, Latundan, and Saba peel wastes are significantly different in terms of their generated voltages. In terms of current generated, the Saba peel waste is significantly different from Lakatan and Latundan peel waste. However, the Lakatan and Latundan peel wastes are similar in terms of the current generated.

The One-way Analysis of the Variance test shows no significant difference in the dissipation rates of the voltages generated from the three varieties of banana peels using the microbial fuel cell. This study concludes that the voltage drops of the three varieties of banana peels are not significantly different.

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