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# Voltage and Ampere Generated from Selected Fruits and Vegetables in Microbial Fuel Cells

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**Abstract**: The effect of both the weight of compost and plant type on voltage and amperage generation was assessed in this study using microbial fuel cells (MFCs). The constructed MFCs, featuring salt bridges and connected plastic containers, comprised six setups with varying weights (5kg and 10kg per compost). Over four days, voltage and amperage readings were collected. The results indicated a significant difference in mean voltage as compost weight rises but on the type of plant. Conversely, there was no significant difference in amperage production concerning both weight and plant type. The discussion suggested that weight has an effect on the production of voltage, possibly influenced by heightened conductivity and microbial activity. The study highlighted the potential of utilizing food waste for energy, emphasizing the significance of weight on voltage generation while acknowledging limitations such as small sample size and challenges in microbial identification. These findings contributed to the implementation of sustainable practices, aligned with environmental goals.

**Keywords:** Microbial Fuel Cells, Bananas, Tomatoes, Sweet potatoes, Renewable Energy, Compost, Food Waste

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## INTRODUCTION

The way energy powers all life on earth is undeniable, but the use of nonrenewable energy sources has resulted in a significant environmental impact due to the residue it leaves behind. Nowadays, the combustion of oil, coal, and natural gas produces more than 85% of the total power used worldwide (Dudin et al., 2019). When fossil fuels are burned, a certain amount of residue is left behind in the form of solids and gasses (e.g. nitrogen oxides, coal ash, fly ash, bottom ash). Further, fossil fuel residue can not be recycled, which leads to environmental pollution. With this, we should seek more alternative energy sources, including renewable resources. Moreover, resources that can generate energy continually without worrying about diminishing in the short or medium term are known as renewable resources. Examples of renewable energy are solar, biomass, geothermal, wind, and hydroelectric energy (Güney, 2019). In addition, bioenergy is a natural alternative to producing energy. Therefore, bioenergy can be used to generate electricity using organic waste such as food waste.

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Food waste is a type of municipal solid waste (MSW) that is becoming more widely recognized (Chen et al., 2023). According to the Department of Science and Technology's Food Banana and Nutrition Institute (DOST-FNRI), the Philippines produce 1,717 metric tons of food waste daily. Frequently, food waste is being disposed of in landfills. This explains why a significant amount of fugitive greenhouse gas (GHG) is being emitted due to food waste having the largest methane potential (Badgett and Milbrandt, 2021). Finding a sustainable method of disposing of food waste is absolutely necessary, as sending food waste to landfills is neither financially viable nor ecologically responsible.

Due to the depletion of fossil resources and worries about climate change, people are growing more interested in renewable energy (Mohammadi et al., 2021). With this, the implementation of food waste-to-energy is something that would be very beneficial for society as a whole. In addition, food waste has great potential for generating energy. Rojas-Flores et al. (2020) provided information on fruit wastes that can be used as renewable energy and an alternative method for producing electricity called microbial fuel cells (MFC). Caruso et al. (2019) stated insights on using biogas from food waste to generate renewable energy. Breunig et al. (2017) estimated that California's food waste can generate 530 Megawatts of electricity. Finally, Kalagbor et al. (2020) provided information on electricity generation from discarded tomatoes, bananas, pineapple fruits, and peels.

According to previous studies, it was recommended to use tomatoes and bananas since tomatoes contain redox-active molecules, specifically carotenoids and flavonoids, and their natural lycopene can encourage the generation of electricity. Tomatoes also have high conductivity, and the quercetin in them may exhibit electrochemical activity in an aqueous medium(Fogg et al., 2015). In addition, bananas are available all year round, and they are rich in carbohydrates and other essential nutrients that can enhance microbial growth. Banana biomass, including both fruit and peels, has been used to produce methane gas and biofuels, and banana peels in particular have been shown to result in higher rates of methane production compared to other fruit wastes (Essien et al., 2005). By utilizing these fruit wastes, which are typically discarded and can have negative impacts on the environment and health, bio-energy can be produced through microbial fuel cells.

Similarly, sweet potato waste was used in this research. The skin peels of sweet potatoes are a vital source of fermentable sugars which is a potential source for bioethanol production (Bhuvaneswari & Sivakumar, 2019).

The study aimed to evaluate the feasibility of using microbial fuel cells (MFCs) to generate electricity from various types of fruit and vegetable waste. The study also intended to investigate the potential use of MFCs in providing electricity to the Sitio Makabuhay community. The study also identified if weight has an effect on the amount of voltage and current to be produced. Ultimately, the goal was to promote sustainable energy generation by utilizing fruit and vegetable waste as a renewable energy source.

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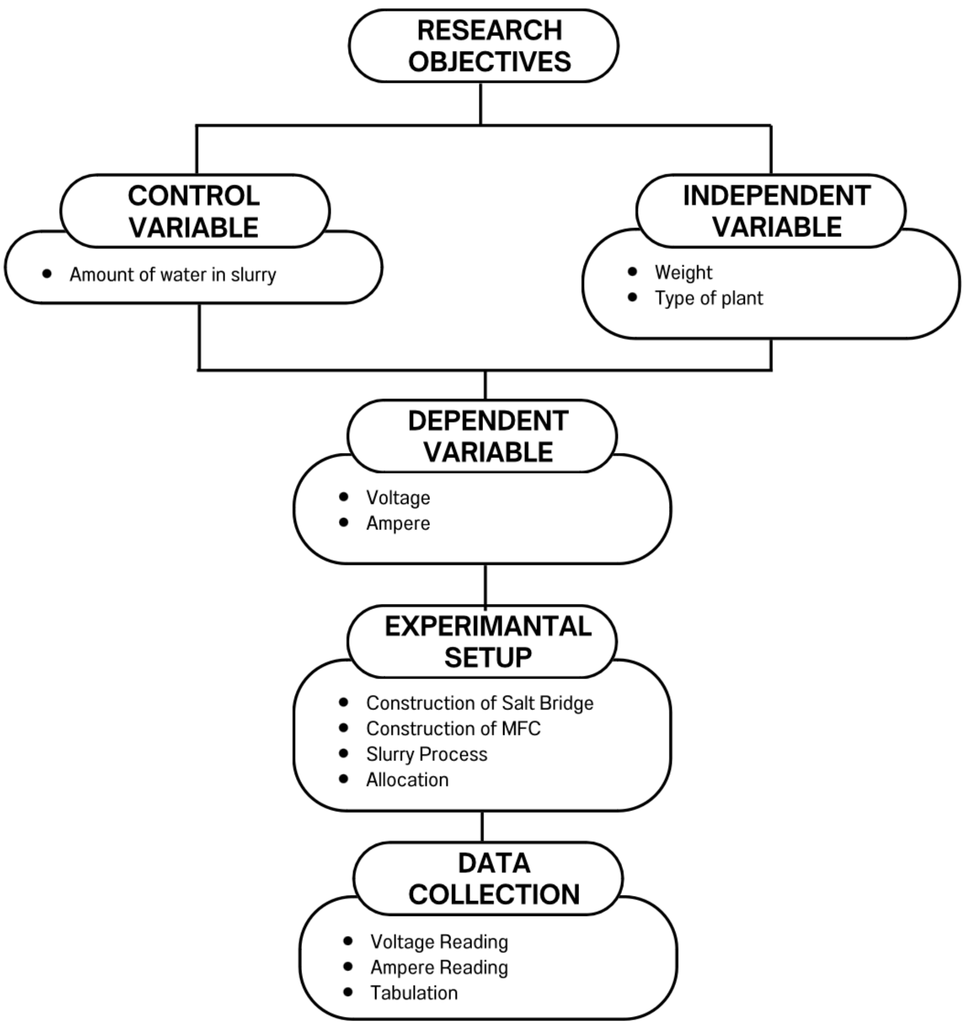
## METHODOLOGY

The study adopted a quantitative research approach, employing a true experimental design to systematically investigate the impact of both weight and the type of plant on the generation of voltage and amperage. Over a span of four days, continuous readings of voltage and amperage were collected. Notably, the voltage data exhibited a normal distribution, validating the use of a Two-Way ANOVA to discern the effects of weight and plant type. In contrast, the amperage data did not conform to a normal distribution, leading to the application of the Kruskal-Wallis test—a non-parametric alternative—to effectively analyze the given dataset.

**Figure 1**

*Research Design*



**Sampling Procedures**

The Simple random sampling technique was used in gathering samples for the experiment. Waste fruits and vegetables were obtained from local farmers and markets in Sto. Cristo St. Binondo, Manila. Samples were placed in polyethylene bags in order to facilitate degradation by microorganisms.

**Figure 2**

*Gathered samples in polyethylene bags*

## Sample Preparation

### Salt Bridge

Agar and potassium chloride (KCl) were used in making the salt bridge. Two hundred fifty mL of water was heated. Once the water was warm enough 18.64 g of potassium chloride (KCl) was mixed into the water. Once potassium chloride (KCl) was dissolved, 20 g of agar was added and mixed consistently until boiling. Heat was turned off in order to let the solution cool off, and gently pour the solution into the PVC pipes.

**Figure 3**

*Construction of Salt Bridge*

**Construction of the MFC Chambers**

Twenty-one liter rectangular plastic containers were used to construct a DIY Microbial Fuel Cell. Two Rectangular plastic containers were connected by a salt bridge in order to keep the solutions electrically neutral in order to allow the free flow of ions from one cell to another (Libretexts, 2023). The connected salt bridge was sealed using Vulcaseal in order to avoid leaking. A wire mesh was placed in each container which was connected to a copper wire in order to be able to collect data using a multimeter.

**Figure 4**

*Microbial Fuel Cell chambers*

**Process of Making the Slurry**

Wastes were blended thoroughly before placing them inside the constructed microbial fuel cells (MFCs). Then, 2 kg of water was added until proper consistency was formed. Finally, place the lid on, ensuring that the MFCs were air tight.

**Figure 5**

*Blending the Slurry*

**Biomass Allocation into Different Composites**

A total of six setups were done per compost. It was recommended by Kalagbor IA et al. (2020) to use different weights of samples in order to test if it has a difference in voltage and ampere production. That is why the six setups consisted of a triplicate of 5 kgs and 10 kgs per compost.

**Table 1**

*Allocation of Tomato, Banana, Potato, and Sweet Potato Biomass*

| Composition | Tomato | Banana | Sweet Potato |
|---|---|---|---|
| **1:0:0** | 5kg | — | — |
| **0:1:0** | — | 5kg | — |
| **0:0:1** | — | — | 5kg |
| **2:0:0** | 10kg | — | — |
| **0:2:0** | — | 10kg | — |
| **0:0:2** | — | — | 10kg |

***Total Weight:*** *135 kg*

**Data Collection**

The fruit and vegetable waste were analyzed by the amount of voltage and ampere it produced with the help of microbial fuels.

***Voltage***

Voltage reading was taken using a multimeter connected to the terminals of the electrodes. Readings were presented in tables in order to compare voltage readings from different composites.

***Ampere***

Ampere reading was taken using a multimeter connected to the terminals of the electrodes. Readings were presented in tables in order to compare current readings from different composites.

## Data Analysis

### *Analytic strategy*

Through 4 days worth of voltage and current readings gained from each of our fruit and vegetable waste samples, data was compiled and organized into tables to better compare and contrast how effective each food waste is in terms of generating electricity. Two-way ANOVA analysis was used in order to identify how different fruits and vegetables, as well as their weights, independently and interactively influence the energy output. However, after checking the homogeneity test and normality test of the data for amperage, the p-values were both less than 0.001, indicating that our data was not normal. Kruskal-Wallis test, a non parametric test was utilized in order to further analyze the significant difference between the not normally distributed dependent and independent variables. With this, the effect of weight on the production of voltage and amperage can be determined.

## RESULTS

Through statistical analysis, the reliability of food waste as a renewable energy source and the optimal fruits and vegetables for energy production were assessed. Descriptive statistics, two-way ANOVA, one-way ANOVA, and Kruskal-Wallis test, table, and bar graphs were employed to compare and contrast the voltages and amperes collected from the selected fruits and vegetables according to weight and type of plant.

**Table 2**

*Mean and Standard Deviation of Voltage and Ampere*

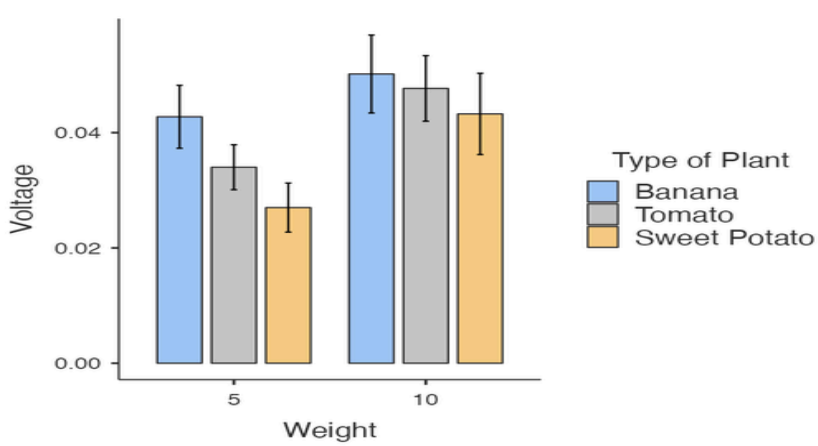
| Type of Plant | Weight (kg) | Voltage (V)* | Ampere (A) |
|---|---|---|---|
| **Banana** | 5 | 0.0428 ± 0.0189 | 0.167 ± 0.172 |
| | 10 | 0.0502 ± 0.0420 | 0.650 ± 0.709 |
| **Tomato** | 5 | 0.0340 ± 0.0135 | 0.392 ± 0.156 |
| | 10 | 0.0477 ± 0.0197 | 0.442 ± 0.350 |
| **Sweet Potato** | 5 | 0.0270 ± 0.0147 | 0.358 ± 0.231 |
| | 10 | 0.0432 ± 0.0244 | 0.808 ± 0.878 |

**The significant difference in voltage was based only on the weight and not the type of plant*

In terms of voltage generation, 10 kg of banana generated the highest mean voltage of 0.0502 V (SD = 0.0420), while 5 kg of sweet potato resulted in the least mean voltage output of 0.0270 V (SD = 0.0147). It was also observed that there was a significant difference in voltage according to weight and not the type of plant since the p value for weight was .009, and the p value for the type of plant was .141. (see Appendix B-1 and Figure 6).

**Figure 6**

*Bar Graph of Voltage Production*



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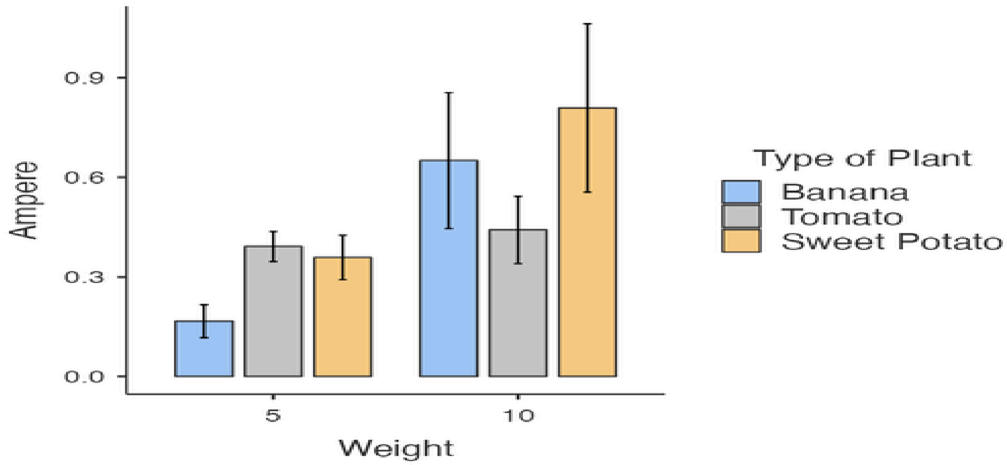
As for ampere generation, 10kg of sweet potato produced the highest amperage of 0.808 A (SD = 0.878), while 5 kg of banana generated the least amperage of 0.167 A (SD = 0.172). After doing Kruskal-Wallis test, there was no significant difference in ampere according to type of plant and weight since the p-value were .083 and .055, respectively (See Appendix B-5).

**Figure 7**

*Bar Graph of Ampere Production*




**There was no significant difference in ampere according to weight and the type of plant*

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It was also observed that there was possible buildup of microorganisms in the setups since there was evidence of gas production, change of smell, and the water which was originally clear, turned a bit murky and turbid.

## DISCUSSION

There were two key findings in the present research. First, there was a significant difference in production of voltage to weight but not on the type of plant . Second, there was no significant difference in production of amperage to the weight and the type of plant.

The data indicated an increase in mean voltage as the weight of the plants increased from 5 kg to 10 kg for all three plant types (banana, tomato, sweet potato). It was suggested that there was a rise in the overall conductivity of the material. Higher conductivity allowed for a better flow of electrical charge, leading to an increase in voltage (Rojas-Villacorta et al., 2023). Further, based on the findings of Kalagbor and Tb (2019), a more plausible explanation was that compost with a higher weight might have retained more moisture. Moisture could act as a conductor, facilitating the movement of electric charge within the compost material and leading to an increase in voltage. Microorganism buildup also supported the production of voltage. Microorganisms played a vital role in the composting process. An increase in compost weight could have signified a more significant microbial population. Microbial metabolic activities might have produced compounds that contributed to electrical conductivity, influencing the voltage. These results supported the claim that weight and voltage had a direct relationship with each other.

However, in terms of amperage, the claim that amperage increases as weight increases was rejected. Although there was an increase in production, it did not result in a proportional increase in amperage. Nevertheless, Ohm's Law (I=V/R) could support the increase in the production of amperage since it stated that if the voltage across a circuit or system increased, the current flowing through it would also increase, assuming the resistance remained constant. The results contradicted the claim of Kalagbor IA et al. (2020), which stated that the production of amperage would increase as weight increased. The lack of significance could have been due to the variability in the data or insufficient sample size. Increasing the sample size or improving measurement precision might have revealed significant differences.

These results build on existing evidence of the feasibility of MFCs in producing electricity when using compost from selected fruits and vegetables. Finally, information was provided by this study on how the successful implementation of food waste for energy using MFCs could contribute to reducing greenhouse gas emissions and mitigating climate change impacts.

Acknowledging and addressing limitations in this study was crucial for future research. One limitation in this study was the reliance on a relatively small sample size, which might have affected the findings. Another limitation in this study pertained to the identification of microorganisms and the measurement of conductivity.

Given the limitation related to a small sample size, it was recommended that future studies increase the number of setups to enhance the reliability of data. Additionally, for the limitation related to microbial identification and conductivity measurement, future research should explore and employ advanced techniques that offer increased accuracy and precision in identifying microorganisms and measuring conductivity. Utilizing these methods might contribute to a more reliable interpretation of the data.

In conclusion, our study suggested potential in using food waste for energy. The findings indicated there was a significant difference in voltage according to weight but not the type of plant. As for amperage, there was no significant difference in amperage according to weight and type of plant. While additional research was needed to address the limitations of this study, the current findings supported the implementation of food waste for energy using MFCs, which could contribute to reducing greenhouse gas emissions and mitigating climate change impacts.

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**APPENDIX A:**

## APPENDIX B:

### Appendix B-1

*Two Way Anova Analysis for Voltage*

| | Sum of Squares | df | Mean Square | F | p |
|---|---|---|---|---|---|
| **Type of Plant** | 0.00154 | 2 | 7.713–4 | 2.021 | 0.141 |
| **Weight** | 0.00279 | 1 | 0.00279 | 7.301 | 0.009 |
| **Type of Plant * Weight** | 2.47e–4 | 2 | 1.24e–4 | 0.324 | 0.725 |
| **Residuals** | 0.02519 | 66 | 3.82e–4 | | |

### Appendix B-2

Homogeneity of Variances Test (Levene's)

| F | df1 | df2 | p |
|---|---|---|---|
| 1.38 | 5 | 66 | 0.243 |

**Appendix B-3**

Normality Test (Shapiro-Wilk)

| Statistic | p |
|---|---|
| 0.976 | 0.181 |

**Appendix B-4**

Test for Equality of Variances (Levene's)

| F | df1 | df2 | p |
|---|---|---|---|
| 7.131 | 5.000 | 66.000 | < .001 |

**Appendix B-5**

Kruskal-Wallis Test

| Factor | Statistic | df | p |
|---|---|---|---|
| Type of Plant | 4.983 | 2 | 0.083 |
| Weight | 3.691 | 1 | 0.055 |