39.2
1.4
11.6
9.5
31.8

TITLE:
Electricity from Soil Microbes – Effect of Organic Waste Additions

Student Name: N. Muhammad Luqman
Grade: 7
School: i-Max Nursery and Primary School
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Introduction

Soil contains electrogenic microbes that metabolise organic matter and release electrons. A microbial fuel cell (MFC) captures this process by using an anode embedded in the soil and a cathode exposed to oxygen. The electrons flow through an external circuit, producing measurable voltage. This project investigates how the addition of different organic wastes (potato peel, beetroot waste, onion waste, sugarcane waste) as compared to plain soil influences the voltage output.

Hypothesis

It was hypothesised that jars with added organic waste would produce higher voltages compared to plain soil because the extra organic material would provide more substrate for microbial metabolism, thus enhancing electron transfer to the anode.

Variables

- **Independent variable:** Type of organic waste added (potato, beetroot, onion, sugarcane, none)
- **Dependent variable:** Voltage output (volts) measured between the anode and cathode
- **Controlled variables:**
  - Jar size: 3 litre containers for each unit
  - Soil amount: 2.750 kg of soil added to each jar
  - Electrode material (pencils sharpened)
  - Electrode placement (one deep inside – anode; one near surface – cathode)
  - Salt-vinegar ionic treatment added in each jar

- Soak period: 10 days before first reading, then addition of raw lid variation and 1 more day before second reading

Materials & Methods

Materials:
10 jars (3 litre each), each filled with approximately 2.750 kg of garden soil.

Organic waste: potato peel, beetroot waste, onion waste, sugarcane waste; pencils sharpened at both ends (used as electrodes),salt, vinegar, wires with crocodile clips; multimeter.

Methods:

1. Label jars for five conditions: Soil only, Potato waste, Beetroot waste, Onion waste, Sugarcane waste — two jars each (A and B).
2. In each jar, insert one pencil deep inside (anode) and one pencil near the surface (cathode).
3. Add salt solution and vinegar to each jar to improve ionic conductivity in the system
4. Allow the jars to sit for 10 days for microbial **colonization** and activity under these conditions.
5. After 10 days measure the voltage between the two pencils (anode-cathode) using the multimeter — this is the "pencil reading."
6. Introduce a "raw lid" piece (2.0 mm thickness) on each jar as a variation; after 1 day measure the voltage again — this is the "raw-lid reading."
7. Record for each jar: pencil reading, raw-lid reading, days for pencil reading, days for raw-lid reading.

Data & Results

S.No	**Jar Name (Condition)**	**Pencil Reading (V)**	**Raw-Lid Reading (V)**	**Days for Pencil**	**Days for Raw Lid**
1	Onion A	0.08	0.09	10	1
2	Onion B	0.02	0.02	10	1
3	Potato A	0.08	0.05	10	1
4	Potato B	0.01	0.13*	10	1

S.No	Jar Name (Condition)	Pencil Reading (V)	Raw-Lid Reading (V)	Days for Pencil	Days for Raw Lid
5	Beetroot A	0.03	0.07	10	1
6	Beetroot B	0.07	0.17	10	1
7	Sugarcane A	0.03	0.06	10	1
8	Sugarcane B	0.03	0.02	10	1
9	Soil Only A	0.14	0.01	10	1
10	Soil Only B	0.07	0.14	10	1
	Total Voltage	**0.56**	**0.76**		

* The reading for Potato B raw-lid may include a scribble marking 0.13.

Discussion & Analysis

- Using a standard jar size of 3 litre and 2.750 kg soil per jar ensured consistency across all tests.
- One interesting variation: adding more soil (i.e., increasing the volume beyond 2.750 kg or using a larger jar) could potentially increase microbial biomass → possibly higher voltage, *but* it could also increase internal resistance (longer ion path, more moisture/air gradients) which may reduce voltage. Research suggests that when the volume of the chamber increases, the power density drops because internal losses grow.
- Similarly, adding more salt water (increasing ionic strength) often improves conductivity and can increase voltage initially by lowering internal resistance. But too much salt can harm the microbes, reducing output.
- In this experiment, the "raw-lid" variation raised the total measured voltage (0.76 V) compared to the pencil only reading (0.56 V) — indicating that adjusting the jar condition (lid, possibly changing gas/oxygen diffusion or ionic paths) influences performance.
- The highest individual reading was 0.17 V (Beetroot B raw-lid). To get ~3 V (enough to light many small LED bulbs which often require ~2 V – 3 V depending on type), you would need to connect multiple jars in series. For example, if an average jar gives

~0.1 V to ~0.2 V, you would need roughly 15–30 jars in series to reach ~3 V (assuming ~0.1 V per jar: 30 jars × 0.1 V = 3 V; if ~0.2 V per jar: 15 jars × 0.2 V = 3 V).

- Bear in mind: LEDs also need sufficient current (mA) — voltage alone doesn't guarantee it will light; your system must also supply enough current and lower internal resistance. Many educational MFCs manage voltages but very low currents, so powering an LED might require stacking and parallel cells.

Conclusion

The experiment demonstrates that soil-based microbial fuel cells can generate measurable voltages under simple conditions (3 litre jar, 2.750 kg soil, pencil electrodes, salt/vinegar ionic treatment). Under the given conditions, plain soil (control) produced one of the highest readings, and the lid variation appeared to improve output slightly. The findings show that simply adding organic waste doesn't guarantee higher electricity production — other factors like electrode arrangement, moisture/ion paths, salt concentration, jar environment matter. Also, for powering an LED (~3 V), one must consider stacking multiple cells and ensuring current is sufficient.

Future Work

- Test different electrode materials (graphite rods, carbon cloth) for improved electron transfer.
- Measure current (in mA) as well as voltage to calculate power output (mW) and compare practical usefulness (lighting an LED or small sensor).
- Experiment with jar size/soil mass (e.g., 3 litre vs 5 litre; 2.750 kg vs 3 kg soil) to evaluate how increasing volume or mass affects voltage and power density (noting that larger volumes may reduce power density).
- Vary salt/water addition systematically (e.g., 1% vs 3% salt solution) to see optimum ion conductivity without harming microbes.
- Stack multiple jars in series and/or parallel to reach higher voltages (e.g., 3 V) and test lighting a small LED, recording how many units are needed under actual conditions.
- Monitor how long stable voltage is maintained over time (e.g., daily readings over several weeks) to evaluate durability of the system.

Acknowledgements & References

References:

- Science Buddies: “Spice Up the Power of a Microbial Fuel Cell with a Dash of Salt.” Science Buddies
- Jiang YB et al., “Characterization of Electricity Generated by Soil in Microbial Fuel Cells.” PMC
- Flimban SGA, “Overview of Recent Advancements in the Microbial Fuel Cell.” MDPI

Working technique (Images) : For References


POTATO
POTATO
ONION
ONION
ONLY SOIL
ONLY SOIL
SUGAR CANE
SUGAR CANE
BEETROOT
BEETROOT

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