Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 1 (2024)

Living Plant or Tree as a Renewable Energy Source of Long Lasting Battery

[1]Purnima K Sharma, [2]TJVS Rao, [3]TVNL Aswini, [4]Dinesh Sharma
[1,3]Department of ECE, Sri Vasavi Engineering College, Tadepalligudem, AP, India, 534101
[2]Department of ECE, Sasi Institute of Technology and Engineering, Tadepalligudem, AP, India, 534101
[4]Department of ECE, Chandigarh College of Engineering and Technology, Chandigarh, India

Abstract:- The increasing demand for energy due to rapid population growth has led to a focus on renewable resources as the primary solution. Non-renewable energy sources result in harmful gas emissions during energy production, necessitating the development of sustainable alternatives. This study explores the generation of electricity from living plants using photosynthesis. Through primary experiments, the electrical energy intensity from living plants is determined. The energy is harnessed by the flow of ions from electrodes inserted into the plant roots. Various plant species and electrode combinations are investigated, producing different voltages suitable for powering low-power devices like LED lights, digital clocks, and calculators.

Keywords: *Energy Harvesting, Living Plants, Green Energy, Renewable and Non-renewable Energy.*
Email: aswini.thota@srivasaviengg.ac.in

1. Introduction

Energy plays a vital role in all aspects of life, and the natural environment has been a constant source of inspiration for researchers. Energy sources can be classified into two categories based on their availability: renewable energy sources and non-renewable energy sources. Renewable energy sources can be replenished and reused indefinitely, providing an unlimited supply over extended periods. Examples include solar, wind, tidal, and certain plant-based sources [4]. In contrast, non-renewable energy sources cannot be replenished, and their supply is limited. Examples include petrol, coal, oil, nuclear, and natural gas, which require significant time to regenerate [2,8]. The combustion of non-renewable sources emits harmful gases like nitrogen and carbon dioxide, posing health hazards and polluting the environment. These emissions contribute to the greenhouse effect, leading to climatic changes.

Achieving a balance between cost-effectiveness and renewability has been a challenging endeavor in the realm of green energy. However, a promising solution has emerged, leading researchers worldwide to explore substitutes for fossil fuels. Among these alternatives, bio-fermentation stands out as a process that harnesses energy from various plant materials. Surprisingly, living plants themselves play a role in energy generation. Through the collaboration of living plants and microorganisms, a plant microbial fuel cell facilitates the production of electricity. This innovative approach yields clean and renewable energy without any adverse impact on the plants. In the literature, studies have demonstrated the generation of electricity using citrus acid fruits [3,5,10]. Although lemon and potato-based batteries have limitations in terms of duration and power output, they have been instrumental in sparking interest in renewable energy from living plants. Commercially, a single lemon-based battery falls short of providing sufficient current to light up a bulb due to its low output [9,11,12]. However, researchers have explored various crop options, such as grass species, sugarcane, maize, and corn, which have been used for biomass production worldwide for many years. Numerous experiments have been conducted on living plants to gauge their electrical potential and assess their viability as sustainable energy sources.

The University of Wageningen in the Netherlands conducted research that revealed an output power of 0.4W at a one-meter distance from the plants. Other researchers have measured the electric potential of numerous trees, estimating the average potential of a tree to be around 200mV [11]. This paper primarily centers on the utilization of plants or trees as a renewable energy source. Plants have the capability to generate energy over extended periods. Through the exploration of various plants and electrode combinations, distinct voltages have been observed [1, 6, 7]. By conducting diverse experiments on different plants, it has been determined that the banana tree exhibits the highest voltage generation.

2. Methodology

Biomass, which is the plant material, is also a renewable source of energy source as it produces its energy by the process of photosynthesis using sun. Photosynthesis is the process through which plants prepare their own food by using the energy of sunlight to produce glucose from carbon dioxide and releases the oxygen to atmosphere. The excess amount of glucose is collected at the roots of the plant [14]. Microorganisms under the roots will break down the glucose. Electrons and protons appear in this break down process as shown in Fig. 1. Plant-based microbial fuel cell plants use sunlight to transform carbon dioxide into organic molecules. Some of the chemicals formed in this manner are used by the plant for growth, while the rest is discharged from roots.

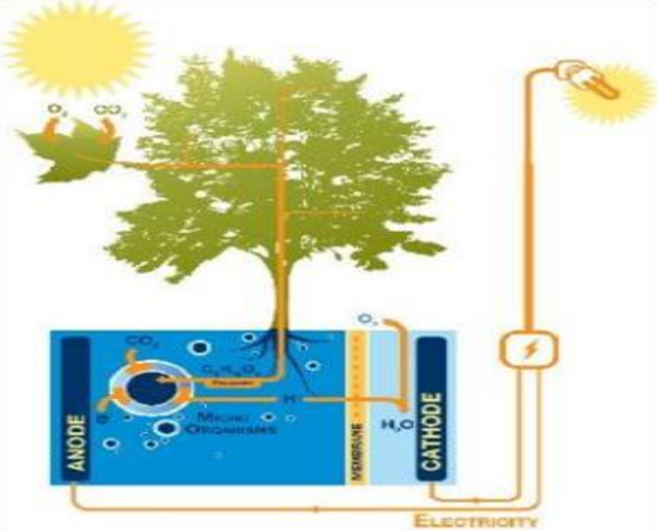

Figure 1. Mechanism of Generation of Electricity from Living plant

The experiment set up flowchart is depicted in the Fig.2. For this experiment, suitable plant species were identified and selected based on their photosynthetic efficiency, growth rate, and availability. Emphasis was placed on plants known to produce excess glucose and capable of thriving in the experimental conditions.

2.1 Microbial Fuel Cell Design

A microbial fuel cell (MFC) system was designed with two main compartments: the anode and the cathode. To facilitate electron collection and transfer, the anode and cathode were constructed using appropriate electrode materials.

- Anode Setup: An appropriate anode material, such as carbon or Zinc, was selected to act as the electron collector. The anode electrode was then prepared with an optimal surface area to maximize electron collection efficiency.
- Cathode Setup: A suitable cathode material, such as Aluminum or carbon felt, was chosen to facilitate the oxygen reduction reaction. The cathode electrode was assembled with the required surface area to support the reaction.
- Membrane: To prevent direct contact between the anode and cathode while allowing for ion exchange, a membrane was introduced to separate the compartments.

The growth conditions for the plants were carefully controlled. Consistent and controlled light exposure was provided to support photosynthesis, using appropriate light sources to mimic natural sunlight. A controlled and stable temperature suitable for the selected plant species and microorganisms was maintained throughout the experiment. The carbon dioxide concentration around the plants was monitored and maintained at an optimal level to support photosynthesis.

2.2 Glucose Collection and Microbial Degradation

- Glucose Collection: Excess glucose produced during photosynthesis was collected non-invasively from the roots of the plants to ensure their health and growth.
- Microorganisms: Soil samples were collected from the vicinity of the plant roots to identify and characterize the microorganisms present. Special attention was given to microorganisms capable of breaking down organic substances and releasing electrons during this process.
- Microbial Degradation: The collected glucose was allowed to undergo degradation by the soil's microorganisms, resulting in the release of electrons and protons.

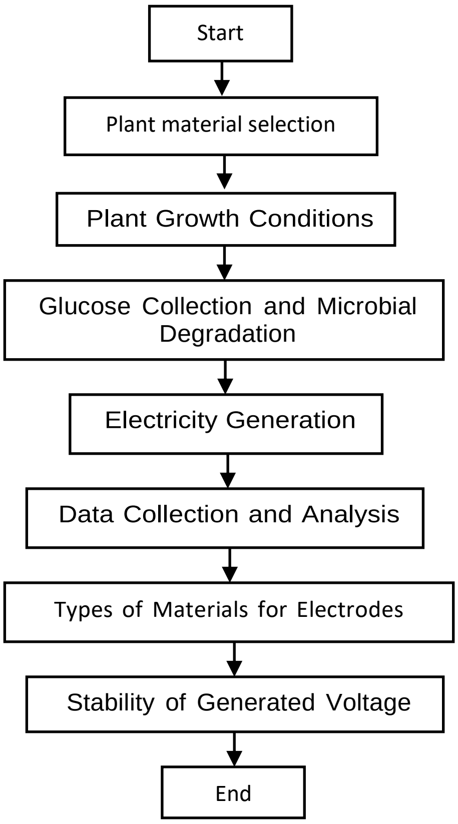

Figure 2. Flow chart for the Generation of Electricity from Living plants

2.3 Electricity Generation

- Electron Collection: The anode electrode was strategically positioned near the plant roots to collect the released electrons during microbial degradation [13].
- Electricity Production: By connecting the anode and cathode to an external circuit, the collected electrons were allowed to flow, generating direct current (DC) electricity.

2.4 Data Collection and Analysis

- Electricity Output Measurement: Regular measurements of the generated electricity output were recorded from the microbial fuel cell system under different growth conditions and light intensities.

- Data Analysis: The collected data was analyzed to assess the electricity generation performance of the plant-based microbial fuel cell system. Results were compared under varying conditions to evaluate system efficiency and stability.

2.5 Types of Materials

After plants undergo electrochemical reactions, they generate electrons, resulting in the production of electrical potential energy. The electrons flow from the cathode to the anode, with each electrode connected to a separate pole of the electric circuit. The selection of electrode materials is guided by the electrochemical series, which ranks them based on their potential to produce electrical energy. For the purpose of generating potential, various materials such as Iron (Fe), Zinc (Zn), Copper (Cu), and Aluminum (Al) are employed for comparative analysis of electricity generation in different plants. Nickel (Ni), Tin (Sn), Lithium (Li), Barium (Ba), Sodium (Na), Potassium (K), Magnesium (Mg), Manganese (Mn), Lead (Pb), Aluminium (Al), Mercury (Hg), Gold (Au), Silver (Ag), and Platinum (Pt) are also typical electrode materials [13]. These materials are critical in converting plant-generated electrons into useful electrical energy.

Electrodes with higher potential values are on the right, while those with lower potential values are on the left. Following rigorous examination of all electrode pairings, it was established that zinc and copper make the most effective pair, producing the maximum voltage. Zinc and copper electrodes were employed continuously throughout the experiment. These electrodes are uniform in size, measuring 150mm long and 50mm wide. When the electrodes are connected in parallel, the current increases, whereas connecting them in series results in higher voltage levels.

3. Experimental Results

There are numerous electrode types available for use in energy generation. Among these, the zinc and copper combination is the most effective and easily accessible, with the maximum power output. Zinc serves as the anode in this pair, while copper serves as the cathode. The electrochemical potentials of the anode and cathode materials determine which material serves as the anode and cathode.

Oxidation and reduction processes occur concurrently during electrochemical reactions. As a result, negative ions flow to the anode while positive ions flow to the cathode. A bulkhead was used to conduct the experiment, with two carbon pieces functioning as the cathode and anode, respectively.

Figure 3. Different Electrodes in Chethy Plant with different electrodes (Zn-Fe and Fe-Al).

Bacteria play an important function in attracting electrons and guiding them towards the cathode. This electrical energy is subsequently used by the cathode to attract protons and mix them with oxygen (O2). As long as the plants are alive and active participants in the energy generating process, this cycle continues indefinitely both during the day and at night. The experiment involved the selection of different plant species, including papaya, chethy, banana, and grass. These plants were chosen for their easy availability, as they thrive in various moist environments. The electrodes were conveniently embedded into the roots and stems of the plants. Fig. 3 illustrates a pair of electrodes, Al-Fe and Zn-Fe, inserted into the roots of the Chethy plant and connected to a millimeter to measure corresponding voltages of 0.315V and 0.628V, respectively.

Figure 4. Electrode Zn-Fe into the roots of the grass

Continuing with the experiment, Fig.4 demonstrates the voltage difference observed in grass. A pair of electrodes, Zn-Fe, was immersed into the roots of the grass and connected to a millimeter to measure the corresponding voltage, which showed a reading of 0.759V. To further enhance the voltage difference, a series connection was tested, resulting in an increase in the voltage level.

Table 1. Variation of voltage in Grass with different pair of electrodes.

S.No	**Pairs**	**Voltage**
1	ZC - AL	0.39
2	AL - FE	0.47
3	CU-FE	0.49
4	FE-ZC	0.62
5	CU - ZC	0.941

Table 1 and Fig.6 present the variation in voltage levels for different pairs of electrodes. It is evident from the data that the Cu-Fe electrode pair yields the highest voltage level of 0.9 volts, surpassing the other electrode combinations. Additionally, the green energy generation from living plants has been accomplished without causing any disruption to the plant's natural growth.

Table 2. Variation of voltage for Papaya tree.

S.No	Timings (PM)	Voltage(mV)
1	3:00	850
2	3:10	910
3	3:15	920
4	3:30	930
5	3:45	934
6	4:00	932
7	4:15	930

To assess the stability of the generated voltage, an experimental setup was created, and the voltage was continuously monitored. Table 2 lists the different voltage values created in a Papaya tree using Copper and Zinc electrodes. The voltage levels rise initially, followed by a period of stability that lasts the entire day. It gives the voltage variation from 3:00 PM to 4:15 PM, with a consistent value of 0.91 volts over that time period. The experiment was extended to the Chethy plant to examine the stability of the generated voltage. Fig.

5 depicts the experimental setup used to test the stability of generated voltage levels employing the Zn-Cu electrode pair. Initially, the voltage rises and eventually settles at one volt.

Figure 5. Voltage in Chethy Plant at different Timings.

Figure 6. Generated Voltages in Banana Tree with Cu-Zn Pair of Electrodes

Also the banana tree produced more voltage than other trees and plants, with a value of 1.078 volts, as shown in Fig. 6 utilizing the Zn-Cu electrode pair. This highlights the banana tree's potential as an efficient source of green energy generation for low-power applications.

4. Conclusion

Finally, this paper successfully demonstrates sustainable energy generation from living plants. To harness electrical potential from diverse plants without interfering with their natural growth, several combinations of electrode pairs, including Zn-Fe, Zn-Al, Al-Fe, Cu-Fe, and Cu-Zn, were used. The results show that the Cu-Zn electrode pair consistently produces the maximum voltage among all tested electrode combinations in various plants and trees. Electricity supplied by living plants can be a dependable and environmentally beneficial alternative for illuminating LEDs, powering digital clocks, calculators, and other low-power gadgets. This study of plant-based microbial fuel cells opens the door for renewable energy production while protecting the natural ecosystem and its important resources.

Conflict of Interests

There are no Conflict of Interests for the article

Refrences

[1] Sy-ruenhuang, chih-hung chung, Hoang-jyhLeu, Chow-Yen-Desmond Sim& Chiu-Yue Lin. “the living banana plant as a long lasting battery cell” International Journal of Green Energy, Taylor and Francis, Feb. 2015.

[2] Kazmerski, L.L., Photovoltaics: a review of cell and module technologies. Renewable & sustainable Energy Reviews 1:71-170, 1970.

[3] Letcher, T.M., and A.W. Sonemann. 1992. A lemon-powered clock. Journal of Chemical Education 69:157-8.

[4] Mano,N.,F.mao, and Heller.2003.Charecteristics of a miniature compartment-less glucose-O2 Biofuel cell and its operation in a living plant. Journal of the American chemical society 125:6588-94.

[5] Muske, K.R., C.W.Nigh and R.D.Weinstein.2007.A lemon cell battery for high power applications. Journal of chemical education 84:635-8.

[6] Oliveira, L., C.S.R. Freire, A.J.D. Silvestre and N.Cordeiro.2008. Lipophilic extracts from banana fruit residues: a source of valuable phytosterols. Journal of agricultural and food chemistry 56:9520-4.

[7] Oliveira, L., D.V. Evtuguin, N.cordeiro, A.J.D.Silvestre, A.M.S.siliva, and I.C.Torres.2006. Structural characterization of lignin from leaf sheaths of “Dwarf Cavendish” banana plant. Journal of Agricultural and food chemistry 54:2598-605.

[8] Thomas, D.S., and D.W. Turner. 2001. Banana (Musa sp.) leaf gas exchange and chlorophyll fluorescence in response to soil drought, shading and lamina folding. Scientia Horticulture 90:93-108.

[9] Swartling, D.j., and C.Morgan.1998, Lemon cells revisited- the lemon-powered calculator Journal Of Chemical Education 75:181-2.

[10] Ensman,R., T.R. Hacker, and R.A.D Wentworth. 1998. Vegetable voltage and fruit “juice”. An electrochemical demonstration. Journal of Chemical Educational 65:727.

[11] Hao Z, Li W, Kan J, Jiang L, Feng C, Yamamoto Y, Harada H, Yasuhara K, Nakamura T, Choo Y Y and Dayou J 2013 A Method to Harvest Electrical Energy from Living Plants J. Sci. Technol. 5 79–90

[12] Rabaey K and Verstraete W 2005 Microbial fuel cells: Novel biotechnology for energy generation Trends Biotechnol. 23 291–8

[13] Vanysek P, Tavassol H and Pilson K-L 2014 Electrochemistry in the Electrochemical Cells: There is More than Just the Working Electrode ECS Trans. 63 145–55

[14] Vasylyshyn, R., Lakyda, I., Yurchuk, Y., Lakyda, M., Melnyk, O., & Bondarchuk, R. (2022, July). Energy potential of woody biomass in Ukraine’s forests and prospects for its utilization as an alternative energy source. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1042, No. 1, p. 012010). IOP Publishing.