Analysis of electricity production through photosynthesis in tropical climate plants

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Abstract. A modern and competent world demands technological innovation in all areas, in the field of electricity, it has gained impressive strength since the development and implementation of clean energy sources, with advances in energy generation that we could hardly have imagined in the last century, but the need for consumption is increasing and the integration of systems capable of producing electricity in a sustainable and economic manner has never been more imperative. The use of a prototype biological cell composed of an external circuit and configured in such a way that it is possible to obtain levels of electrical energy, presents a future option for the self-sustainable development of electricity, everything is carried out together with the photosynthetic process of the plants, in the studied configuration, the oxidation of organic molecules release protons and electrons that travel through the anode and cathode properly integrated, resulting in a flow of energy easily measurable.

1. Introduction

The world's electrical panorama is directed towards energy efficiency, self-sustainability and technological innovation. Every year, international organizations bet on clean energy alternatives, and this thanks to decisive factors, such as low implementation costs, high rates of electrical productivity, and reduction of CO2 emissions. Ecuador currently maintains a very significant participation in the framework of renewable energies. According to official data from ARCONEL, in 2018, the nominal power at the national level was 8,676.89 MW; of which 5,271.74 MW (60.75%) corresponded to plants with renewable energy sources and 3,405.14 MW (39.24%) to plants with non-renewable energy sources [1], [2]. It is a favorable point for the Ecuadorian electrical sector, a large part of these advances go hand in hand with the restructuring of strategic sectors by the Ecuadorian government, advances such as these give room for research and development of non-conventional technologies for electrical production. This research work is based on previous studies related to biomass, using living plants in microbial fuel cells (P-MFC) study introduced and applied in 2012. The system is made up of cells that act together with the natural process of photosynthesis carried out under the incidence of sunlight, more than half of the organic matter is released in the roots initiating an action of bacterial oxidation typical of this cell, resulting in a release of electrons and protons, conducted through the anode, the electrons flow due to the potential difference, from the anode through an electrical circuit with cathode resistance, as a result there is an electricity.

An attractive approach to storing solar energy in chemical bonds is photosynthesis, however it has been a challenge in recent decades to build semi-artificial photosynthetic systems that are efficient at converting solar energy and storing it in the form of chemical bonds of solar fuels. Reference [3]
reviews in detail the molecular level of natural photosynthesis, further demonstrating that artificial photosynthesis is composed of light gathering and charge separation units along with catalytic units of oxidation and reduction of water as well as CO2.

In figure 1, we can see a descriptive diagram of the operation of a microbial fuel cell in 2008, a new renewable-type technology was introduced especially biomass known as the plant microbial fuel cell (P- MFC). Electricity can be generated from living plants and therefore bioelectricity and biomass production can be combined on the same surface, in reference [4] using granular activated carbon for the anode, gold wires as current collector while Teflon-coated copper wires are the connecting anode and cathode.

![Descriptive diagram of microbial fuel cell.](image)

Reviewing, studying the state of the art [5], [6], [7], [8] leads us to the creation of a functional prototype at the beginning of the fuel cell with an internal circuit in addition to the anode and cathode capable of conducting the energy, we adapted the system to a controlled space where we determined the variables such as temperature, soil composition, levels of material conditions, physical effects of metals, in search of a feasible alternative it was decided to carry out a performance analysis [9].

Where, a key factor is the selection of the plant species, 5 different species are used that can be commonly found in the coastal region, and are used for different purposes such as decoration, feeding or medicinal. Naturally, all plants carry out the process of photosynthesis in such a way that there are species that present a greater efficiency in oxidizing organic waste and producing electrons, this being determined by native applications of similar systems where the variety is summarized in two species [10].

It can be pointed out that studies mark a precedent and diverse approaches throughout its integration, it was demonstrated that the voltage levels are low to compete with the energy sources already 100% functional as the solar energy in Ecuador that reaches levels of nominal generation power during 2018 of 27.63 MW with a percentage of 0.52% of plants with renewable energies.

2. Implemented system

To determine an evolutionary cycle methodology by maintaining phases and evaluating the results obtained with each species, determining the production of electricity in the order of (mv) in order to create the ideal prototype or fuel cell as the experimentation progresses [11].

2.1. Definition of the objective.

The scope of this work is defined as the production of energy through the fuel cell prototype, in a controlled soil environment, generating an analysis of its electricity production with potential plant species in the region.
2.2. Prototype functionality.
The biofuel cells present varieties in their structure and efficiency of electrical energy, applications that generate kilowatt-hours according to the amount of units installed in previous studies of P-MFC [6] our prototype includes a smaller and individual generation for each species of plant, obtaining voltage levels, clarifying that the study leaves the possibility open for an application with scopes where the plants are located in large areas obtaining optimal energy levels.

2.3. System description.
The prototype comprises a series of phases. The first phase consists of the elaboration of the stainless steel collecting mesh made up of sections joined in a parallel manner [12] measuring 100 cm x 50 cm each, a 30 cm copper wire weave was implemented on the mesh (Anode) and then a 30 cm copper wire spiral was made (Cathode), which was integrated inside a plastic container of 100x50x50 cm where several layers of Gravel, prepared soil (layer free of residues), Yellow soil, activated carbon and finally the plant were placed.
The carbon layer as a component of the biofuel cell medium is essential, affecting the rapid decomposition of nutrients such as phosphorus, nitrogen, potassium, etc., its use was gradual, all components were linked making sure that there are no effects of the use of metals and their interconnection in a medium produce results that deviate from the feasibility of research, we checked the measurement of voltage and amperage with a digital multimeter (Extech EX430A) for temperature and humidity of the environment we used a digital thermohygrometer (HTC-2) was carried out over 30 days with three measurement intervals morning (09:00 am), afternoon (14:00 pm), night (19:00 pm) The beginning of the second phase is to recognize which are the most suitable plants for the application. Five different types were identified: Chlorophytum Comosum (Love Loop-Ribbon), Capsicum (chili), Ceroxylon Alpinum (Areca Palm), Codiaeum Variegatum (Croto Amarillo) and Aloe Vera (Sábila), all were selected for their resistance to the climate of the coastal region of Ecuador and the average need for water.

3. Results
The results of the application of the fuel cell are shown, of the 5 species evaluated there is a greater energy yield by the species Ceroxylon Alpinum (Palma Areca), with a value of 0.81 v, the trend of yield for the other species of plants is presented in a continuous way in a range that does not vary during the days of sample.

![Figure 2. Species energy trend Ceroxylon Alpinum (Palma Areca)](image)

3.1. Ceroxylon Alpinum (Areca Palm)
In figure 2, the energetic trend of the plant is observed, plant of tropical regions, with an adaptability to warm climates and environments with little incidence of water, of medium size the prototype of fuel cell throughout 30 days with an average environmental temperature of 26-27° centigrade, obtained an average of high generation 0.806 volts.
In figure 3, the energetic trend of the plant is observed, plant from tropical regions, with adaptability to hot and cold climates with low incidence of light, small size fuel cell prototype over 30 days with an average temperature of 26 °C- 27 °C obtained a high average generation 0.485 volts.

3.2. **Chlorophytum Comosum (Love Loop-Ribbon).**

In figure 3, the energetic trend of the plant is observed, plant from tropical regions, with adaptability to hot and cold climates with low incidence of light, small size fuel cell prototype over 30 days with an average temperature of 26 °C- 27 °C obtained a high average generation 0.485 volts.

In figure 4, the energetic trend of the plant is observed, plant from tropical regions, with adaptability to hot climates and environments with high incidence of light, of an average size the fuel cell prototype over 30 days with an average temperature of 26°- 27 °Celsius obtained an average generation with 0.427 volts.

3.3. **Codiaeum Variegatum (Croto Amarillo).**

In figure 4, the energetic trend of the plant is observed, plant from tropical regions, with adaptability to hot climates and environments with high incidence of light, of an average size the fuel cell prototype over 30 days with an average temperature of 26°- 27 °Celsius obtained an average generation with 0.427 volts.

In figure 5, the energetic trend of the plant is observed, plant from tropical regions, with adaptability to hot climates and environments with high incidence of light, of an average size the fuel cell prototype over 30 days with an average temperature of 26°- 27 °Celsius obtained an average generation with 0.427 volts.
3.4. Capsicum (Chili).
In figure 5, the energetic trend of the plant is observed, plant from tropical regions with adaptability to cold climates and environments with high incidence of light, of a medium size, the fuel cell prototype over 30 days with an average temperature of 26 °C-27 °C obtained a high average generation 0.407 volts.

![Figure 5](image)

3.5. Aloe Vera.
In figure 6, the energetic trend of the plant is observed, plant from tropical regions with adaptability to hot climates and almost desert environments, without the need for abundant water, with high incidence of light, of a medium size, the fuel cell prototype over 30 days with an average temperature of 26 °C-27 °C obtained a high average generation 0.25 volts.

The electrical performance of each circuit is within the expected range of 0.8 volts, the conductivity of the anode and cathode was tested, the result of controlling the composition of the soil, contributes adequately to the process of decomposition of organic matter produced by photosynthesis, the species evaluated have differences in their composition, structure, shape, adaptability to temperature, development, however there is an electrical potential in development, within the project factors impossible to control as the climate has been very useful to mark its feasibility of a future prototype.

In the region and with species that have excelled in electrical performance Cerroxyylon Alpinum (Areca Palm) reached a value of 0.81 volts, also developed a set of additional tests consisting of an interconnection of several circuits with different species.

Circuit A is made up of 4 species of plants with connection Codiaeum Variegatum (Croto Amarillo), configuration Washingtonian Robusta series (Fan Palm) new species Chlorophytum Comosum (Love Loop - Ribbon) and Cerroxyylon Alpinum (Areca Palm) where a value of 0.75 volts was obtained, figure 7, refers to the connection of the series circuit of the plants.

![Figure 6](image)

**Figure 6.** Species energy trend Aloe Vera.

Figure 7. Open circuit voltage, series connection.

The serial test was conducted as the third phase of the project in order to obtain accurate and optimal results, showing in figure 8 the energetic trend established for that series circuit, the value obtained is close to reaching the average range of 0.80 volts does not exceed the index; however, the analysis
shows that the functionality of the fuel cell is efficient, the determining factor would be the variety of species.

It is necessary to point out that the production of organic matter that decomposes to promote the oxidation and later production of electrons and proton components is much more complex and outdated within the same circuit.

**Figure 8.** Energy trend, circuit configuration in series analysis with 4 different species for 30 days

Circuit B determines the results, reaching a maximum of 0.456 volts, during the 30 days of measurement, the species interconnected between each other maintain the initial characteristics, as in the example, figure 9 refers to the energetic trend produced in the interconnection of the species. Before the incidence of species with little similarity would be the answer for the performance in terms of electricity production, the species used in this second example of application are **Codiaeum Variegatun** (Croto Amarillo), a species already evaluated, **Washingtonia Robusta** (Fan Palm) and finally **Chlorophytum Comosum** (Love Loop - Ribbon), the electricity produced by the decomposition does not exceed the voltage range of 0.8 volts in this configuration applied.

**Figure 9.** Energy trend, circuit configuration in series analysis with 3 different species for 30 days.

4. Discusison

The conventional electricity supply in the region is prioritized by the use of fossil resources and represents a technology with years of application, achieving a position at the top of the economies of electricity production, our prototype fuel cell integrating a photosynthetic process can be improved considerably from the point of view of structural design so that the cultivation of large systems linked together is possible.

If the fuel cell manages to position itself as an efficient generation technology in the coming years, it can be assumed that it will similarly gain an economy of scale advantage. This will influence the environmental design comparison between fossil-based electricity supply and fuel cells, we have established the limitations of the system related to a minimum scale of study and application of current location and time space, the electricity yield is consistently based on a given region of the Ecuadorian coast, unlike current energies according to [13] which no longer maintain this limiting factor, the key to success lies in the systematic evolution of the project maintaining energy sustainability and the use of indigenous resources that biotechnology offers.

The synchronism between the future competitiveness of these options makes possible the technological development in the electrical markets at world level.

Ecuador is characterized by its close relationship between the exploitation of resources and their preservation in equitable ways, the electrical area is developing gradually in relation to other countries where the use of fossil fuels has decreased dramatically, and new technologies are an important part of their internal electrical markets producing, and commercializing at small and large scales [9]
5. Conclusions
It is possible to conclude that biofuel cells, capable of integrating photosynthetic processes to their principle of operation, reveal the potential to become the new technology producing electricity with great scope after its development, reaching self-sustainability and overcoming the problem of fossil fuels and all collateral damage of use today, we can define several factors to support this conclusion one of them is the accessibility of implementation of prototypes, especially in communities where conventional energy does not reach constantly, in Ecuador remote areas lack electrification according to [10] so the lifestyle is limited to the use of diesel-based energy consumption techniques for lamps, long walks from one village to another to access telecommunications service, refrigeration of food, the use of lithium batteries for flashlights, radios or other devices that do not have an electrical power supply is common, pollution is present with their consumption.
Another factor that makes our study viable and supports the theory of application as a new technology of electrical production is its design at low cost, in figure 10 we can see the operation and descriptive design of the applied prototype the materials used for the study are accessible with affordable prices, providing a point for its broad construction of large-scale systems with projections of electricity production in order of Kilowatt hours per square meter, we can also cite as a factor pressing their various types of applications, throughout our writing we have seen as similar prototypes in totally different environments as the bacterial cell have been used in small pilot devices by Plant-E (2009) [11] which are marketed with a much wider measuring range and with adaptability to extreme climates reached in European winter seasons.
If we land and adapt examples, we can place our prototype for applications in joint lighting systems in recreational spaces, or signalling of short areas of roads, the levels obtained continuously over 30 days with species of Ceroxylon Alpinum (Areca Palm) of 0.8 volts crystallize the applications described.
Evaluating in a general way each phase for which our project has been submitted, we conclude that it is not possible to make a real comparison in this timeline with already established sources of energy production, the scale of differences is significant in important aspects from the magnitudes of generation, to scopes of systems, we have made clear the existing potential of the prototype during the whole process, projections point to its gradual evolution in electricity generation and scope, materializing the initial objective, the generation of electricity through fuel cells with research and development is key to a country of diversity.

Figure 10. Operation diagram, fuel cell
6. References

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