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Epipremnum aureum and *Dracaena braunii* as indoor plants for enhanced bio-electricity generation in a plant microbial fuel cell with electrochemically modified carbon fiber brush anode

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In this study, two different unexploited indoor plants, *Epipremnum aureum* and *Dracaena braunii* were used to produce clean and sustainable bio-electricity in a plant microbial fuel cell (PMFC). Acid modified carbon fiber brush electrodes as well as bare electrodes were used in both the PMFCs. A bentonite based clay membrane was successfully integrated in the PMFCs. Maximum performance of *E. aureum* was 620 mV which was 188 mV higher potential than *D. braunii*. The bio-electricity generation using modified electrode was 154 mV higher than the bare carbon fiber, probably due to the effective bacterial attachment to the carbon fiber owing to hydrogen bonding. Maximum power output of 15.38 mW/m^2 was obtained by *E. aureum* with an internal resistance of 200 Ω. Higher biomass yield was also obtained in case of *E. aureum* during 60 days of experiment, which may correlate with the higher bio-electricity generation than *D. braunii*.

[**Key words:** Bio-electricity; Indoor plants; Modified electrode; Plant microbial fuel cell; Electrode]

Plant microbial fuel cells (PMFCs) represent an emerging technology for sustainable and renewable way of bio-electricity generation by harnessing the photosynthetic ability of plants. In a PMFC, plants utilize sunlight and CO_2 to produced food through the well-known process of photosynthesis. A portion of this produced food is not utilized by the plants and is excreted through the root exudates into the soil. Near plant roots, electrochemically active bacteria degrade these low molecular weight compounds released by the plants and in turns produces carbon dioxide, protons and electrons. By placing two electrodes (anode and cathode) bio-electricity can be produced by harnessing these electrons and protons without the need to harvest the plant (1–4). PMFC technology has the potential to become a source of alternative bio-energy in the future, which is green, clean, renewable and sustainable and at a much lower price than any other form of bio-energy (5). Apart from these, there are major advantages of PMFCs as it can be integrated with agricultural land without compromising the food production (6,7). Furthermore, the PMFC has the potential to be applied to our vast majorities of wetlands and wastelands which are unsuitable for food production and thus, these can be turned into power house of energy (8).

Urban areas are losing the green cover due to the rapid man made development and expansion resulting in compromised air quality. Hence varieties of plants grown in urban areas, especially indoors and roof top gardens can be a source of power in the form of PMFCs, producing bio-electricity as well as conserving our ecosystem (9).

The objective of this research was to design a PMFC in a cost effective way with two different indoor plants, i.e., *Epipremnum aureum* and *Dracaena braunii*. These plants grow very well hydroponically as well as in soil and produce a lot of biomass and hence are much suited to the PMFC research environment. These plants are very popular household indoor plants, which are known to purify the indoor air and are also believed to bring happiness and prosperity (10,11). These plants do not require direct sunlight and grows well in the range of 18–25 °C temperature.

The reason for selecting these plants for the current work was due to their easy availability, low maintenance along with high growth, no competition with food production, and with the opportunity to obtain the dual benefit of bio-electricity generation and purifying air. Therefore, it will be fascinating to make a comparative study of these two plant species to see whether these two indoor plants can produce bio-electricity without compromising their growth. At present, PMFC research is at its nascent stage and bio-electricity generation is very less, however, with extensive research PMFC has the potential to be a source of sustainable and renewable bio-energy in the future. Hence, researchers around the world are constantly engaged in improving the bio-electricity generation capacity of PMFCs, be it the improvement in design, the use of non-chemical catalysts, the electrode modification or its long term power generation capabilities (12–16).

To maintain cost and eco-friendliness, carbon fiber was used as electrode material along with a membrane made from bentonite

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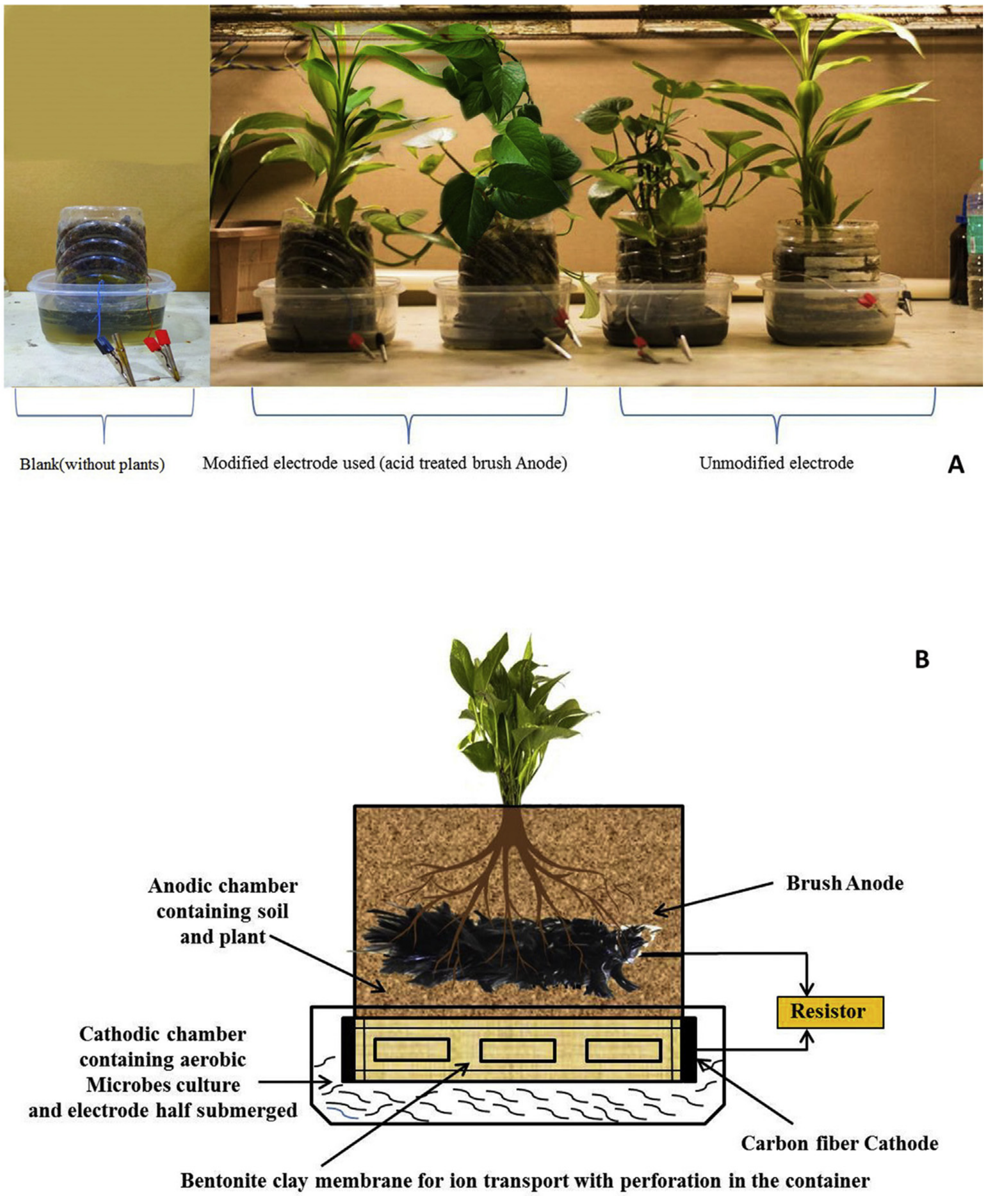

FIG. 1. (A) Experimental setup of PMFC. (B) Schematic representation of plan and cross-section of the experimental setup.

clay. Bentonite is known to have excellent semi permeable properties (17). No chemical catalysts were used in this work and in turns atmospheric oxygen and aerobic bacterial culture were used as the final electron acceptor. Emphasis was laid on anode modification strategies to improve the performance of PMFC by increasing the surface area for the better attachment of more numbers of microorganisms.

MATERIALS AND METHODS

Experimental setup Plastic containers were used for making the plant microbial fuel cell setup with dimension (diameter × height) of the anodic chamber and the cathodic chamber as 12 cm × 8 cm and 14 cm × 5 cm, respectively. A bentonite clay based membrane of thickness 1 cm was prepared and used in the PMFC by placing it in the lower portion of the anodic chamber. At the base of the cathodic chamber perforation was made for effective movements of cations across the chambers. Carbon fiber (Hindoostan Mills Limited, India) was used for making the electrodes. Anode was made up of carbon fiber brush (4 cm in diameter and 6 cm in length and weight 4.7 g) for effective surface area development and was placed perpendicular to the growth of plant roots just above the membrane in close proximity to the roots. The cathode is made up of carbon fiber cloth (2 cm in width and 21 cm in length and weight 4.2 g) wrapped around the membrane as shown in the Fig. 1A and B. The carbon fiber is known to be a good conductor of electricity, also is a durable and suitable material for soil environments (5). The electrodes were connected externally by epoxy copper wire with an external resistance of known value.

Experiments PMFC experiment was initiated by preparing anodic chamber with cow dung and garden soil of IIT Guwahati campus in the ratio of 2:3, respectively. Basic properties of soil and separator used in the experiments are summarized in Table 1. Chemical oxygen demand (COD) was measured at the start of the experiments and after the addition of inoculum on 25th and 45th day (18). For the comparative studies two different plants, i.e., *D. braunii* (lucky bamboo) and *E. aureum* (money plant) were planted into each chamber. Two different setups were prepared containing modified as well as unmodified anode for each plant, hence a total of four different setups was prepared for the experiments. After the

TABLE 1. Basic properties of Soil and Separator used in the experiment.

Parameter	Soil	Separator
pH	7.4	8.2
Moisture content (%)	~65	<10
Density of particle (g/cm^3)	3.256	2.635

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