Red Spinach-A New and Innovative Power Source

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Abstract Different plants extracts have been proven that they are the potential for electricity generation. By immerging two electrodes into the extract to allow flow of ions and then electricity is produced. Different types of electrodes and plant leaves suggested that current and voltage are produced greater or lesser extents where Zn/Cu-based electrodes and PKL extract generates the maximum power output. The results confirmed that electrochemistry is the responsible for electricity generation. LED bulb lighting system using red spinach (*Amaranthus dubius*) extract with and without copper sulphate solution ($CuSO_4 \cdot 5H_2O$). Bio-electrochemical systems show the process of electrical power generation or achieve the reduction reaction with a certain potential poised through electron transfer between the electron acceptor and electron donor. In a Zn/Cu bio-electrochemical cell, the zinc plate losses the electrons, the copper plate gains those electrons and the electrons react with H^+ and Cu^{2+} ions and eventually convert into H_2 and Cu atoms. Finally, H_2 releases from the cell and copper atoms are deposited onto the Cu plate. The experimental was conducted with and without adding copper sulphate solution $CuSO_4 \cdot 5H_2O$ with red spinach extract. A comparative study has been done for with and without secondary salt ($CuSO_4 \cdot 5H_2O$). It is found that the internal resistance has been decreased for

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using copper sulphate as a secondary salt and it was from 0.347 to 0.33 Ω. As a result current has been increased from 1.8 to 7.7 mA and obviously power has been increased from 5.76 to 20.2 mW.

Keywords Red spinach · Extract · Electricity · Secondary salt · Performance · Electrochemistry

1 Introduction

The global economy depends on the production rate of the fossil fuels (oil, gas and coal) [1]. But it is diminishing day by day rapidly [2]. As per the present consumption situations, the reserved oil will be finished within 40 years and gas will be finished within 60 years [3–5]. A lot of researchers proved an inverse relationship between the oil price and activity of the economy. Fossil fuels are the engine of economic activities. The extensive use of fossil fuels are raising the CO_2 in the atmosphere [6–8]. As a result the greenhouse effect is becoming seriously. The greenhouse gases increases the earth's temperature gradually and therefore we are getting a warmer atmosphere and it is collapsing the global environment [9, 10]. It is clear that climate change depends on us. After finishing the fossil fuels Nuclear power may be the alternative sources [11]. But it is very risky and expensive. Now renewable energy may be the alternative energy sources [12]. The meaning of renewable energy sources mean solar energy, wind energy, biogas energy, geothermal energy, biomass energy, water energy, tidal energy, wave energy and OTEC [13]. In the meantime a team of engineers from Washington University has developed low power production device from living plants. Furthermore, different developed and developing countries are harvesting electricity production from different plants and plant leaves [14]. It is mentioned that the role of electrochemistry is the main responsible of electricity production. This paper has expressed the some fundamental parameters to harness electricity from red spinach. The red spinach is one kind of biomass energy sources. It has a great medicinal value. Side by side it has also power value. This paper presents that it is possible to generate electricity using the red spinach. This research work may be the guide line for electricity generation in near future.

2 Methods and Materials

In this section it has been discussed about the selection of electrodes as an anode and cathode and energy source and then after finally understanding the basics of power generation.

2.1 Copper Electrode

The used copper should be highly pure a (above 95%).

2.2 Zinc Electrode

Zinc is called the sacrificial element. It donates the electron.

2.3 Experimental Details

The experimental details are given below:

(a) Twenty-five grams of fresh red spinach leaves were collected from the field and then washed thoroughly with clean water and a fine extract was made using a grinding stone.
(b) The extract was kept in a bottle for about a week being sealed.
(c) A Zn/Cu bio-electrochemical cell is designed where Zn and Cu plates were used as electrodes, red spinach (*Amaranthus dubius*) extract as electrolyte.
(d) An LED bulb was attached to ensure that the bio-electrochemical cell is functional.
(e) Each of the four falcon tubes was filled with pandan leaf extract of 30 ml
(f) Readings of different parameters such as V_{oc} (open circuit voltage), V_L (load voltage), I_{sc} (short circuit current) and I_L (load current) were taken at an interval of 3 min using an ammeter and voltmeter.
(g) Again after adding 1 ml $CuSO_4 \cdot 5H_2O$ in the tubes readings of the same parameters were taken at an interval of 3 min using an ammeter and voltmeter.

For falcon tubes were taken for this research work. Copper is used as an anode and Zinc is used as a cathode. The electrodes are connected in series combinations to flow the electrons for electricity generation.

2.4 Chemical Reactions

At Anode: $Zn \rightarrow Zn^{2+} + 2e^-$

At Cathode: $Cu^{2+} + 2e^- \rightarrow Cu$

Resulting Net Reaction: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$, Where, Cu^{2+} = Reactant ions and Zn^{2+} = Product ions.

2.5 Nernst Equation (Generation of Potential)

$$E = E^0 - (RT/nF)\ \ln Q_c$$

where

E	Cell potential under specific conditions
E^0	Cell potential at standard state condition (known)
R	Ideal gas Constant (8.314 J/mol-K)
T	Temperature in Kelvin (0 °C = 273 K)
n	Number of moles of electrons transferred in the balanced equation
F	Faraday's Constant (i.e. charge of one mole of electrons, 95,484.56 C/mol)
$\ln Q_c$	Natural logarithm of the reaction quotient at the moment in time.

2.6 Reaction Quotient (Q_c)

For the reaction: $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$. We know, $Q_c = [\mathbf{Zn^{2+}}]/[\mathbf{Cu^{2+}}]$

In Nernst equation R and T are constant. If we further consider $T = 298$ K (i.e. 25 °C), then we have, $E = E^0 - (0.02568/n) \ln Q_c$. There is a transfer of 2 electrons. So, $n = 2$. Putting the value we get, $E = E^0 - (0.02568/2) \ln Q_c$. At equilibrium, $E = 0$. Therefore, $0 = E^0 - (0.02568/2) \ln Q_c$. Therefore, $E^0 = 0.01284 \ln Q_c$. Finally, $0 = E^0 - (RT/nF) \ln Q_c$. Therefore, at equilibrium, we have, $E^0 = (RT/nF) \ln Q_c$.

2.7 Necessary Materials

Red spinach (*Amaranthus dubius*), $CuSO_4$ solution, 4 falcon tubes, 8 Zn plates, 8 Cu plates, LED bulb, copper wires, crocodile clips, ammeter, voltmeter.

Figure 1 shows the cycle of the red spinach leaf electricity. It shows the final product from the initial red spinach plant.

Figure 2 shows the 4 unit cells connected in series combination to flow electrons for electricity production.

3 Results and Discussion

In this section, findings of red spinach electrochemical cell with and without secondary salt have been studied. The $CuSO_4\ 5H_2O$ has been used as a secondary salt.

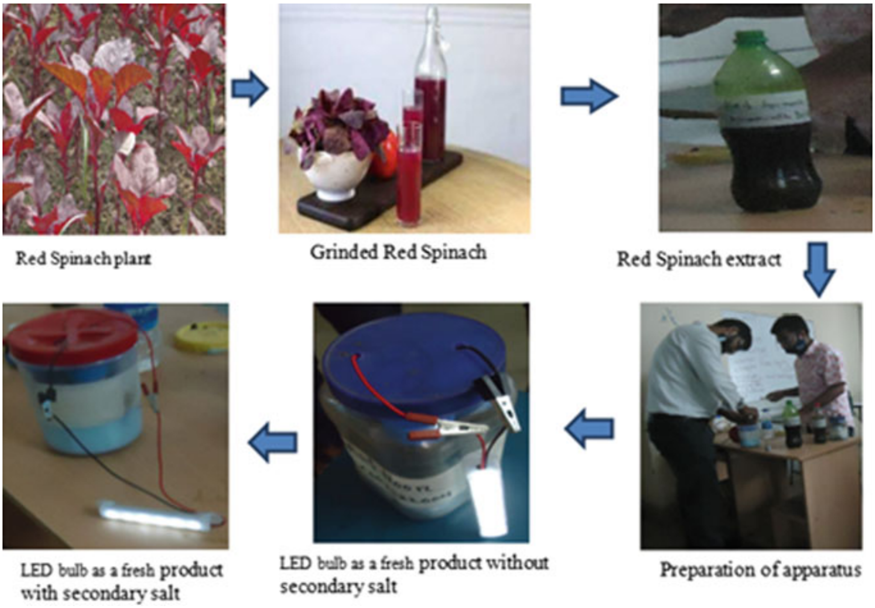


Fig. 1 LED bulb lighting system using *Amaranthus dubius extract* electrochemical cell

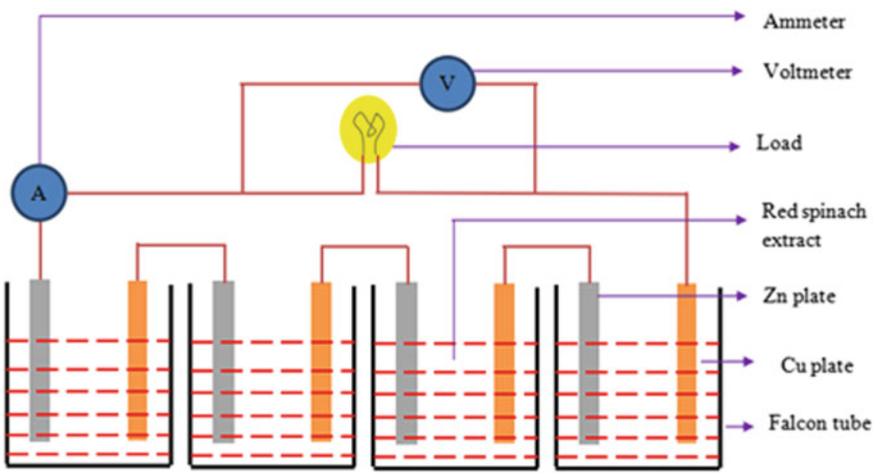


Fig. 2 An experimental set up of an LED bulb lighting system using Red spinach extract

3.1 *Graphical Analysis of LED Bulb Lighting System Using Red Spinach (Amaranthus Dubius) Extract Without* $CuSO_4$

Table 1 shows that the performance of data for LED bulb lighting system using red spinach (*Amaranthus dubius*) extract without $CuSO_4$. The collected parameters were V_{oc}, V_L, I_{sc}, I_L, P_{max}, P_L and internal resistance.

Figure 3 shows that the open circuit voltage remains constant at a peak value of 3.2 V with respect to time duration.

Figure 4 shows that the load voltage also tends to remain constant at a peak value of 2.5 V with respect to time duration.

Figure 5 shows the short circuit current versus time duration curve. It is shown that the I_{sc} (short circuit current) was constant at 1.8 mA up to 15trs and then it

Table 1 Data for LED bulb lighting system using red spinach (*Amaranthus dubius*) extract without $CuSO_4$

Time duration (hr)	V_{oc} (Open circuit voltage) (V)	V_L (Load voltage) (V)	I_{sc} (Short circuit current) (mA)	I_L (Load current) (mA)	Maximum power, $P_{max} = V_{oc} I_{sc}$ (mW)	Load power, $P_L = V_L I_L$ (mW)	Internal resistance, $r_{in} = \frac{V_{oc}}{I_{sc}}$ (Ω)
0	3.2	2.5	1.8	1.6	5.76	4.0	1.78
3	3.2	2.5	1.8	1.6	5.76	4.0	1.78
6	3.2	2.5	1.8	1.6	5.76	4.0	1.78
9	3.2	2.5	1.8	1.6	5.76	4.0	1.78
12	3.2	2.5	1.8	1.6	5.76	4.0	1.78
15	3.2	2.5	1.8	1.6	5.76	4.0	1.78
18	3.2	2.5	1.8	1.6	5.76	4.0	1.78
21	3.2	2.5	1.7	1.5	5.44	3.75	1.88
24	3.2	2.5	1.7	1.5	5.44	3.75	1.88
27	3.2	2.5	1.7	1.5	5.44	3.75	1.88

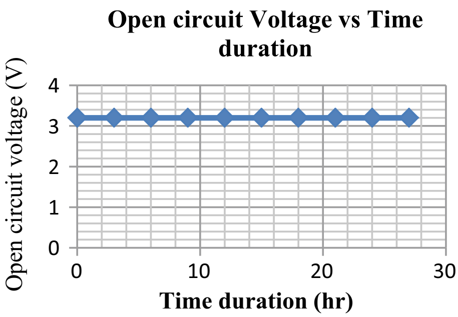


Fig. 3 V_{oc} (open circuit voltage) versus time duration

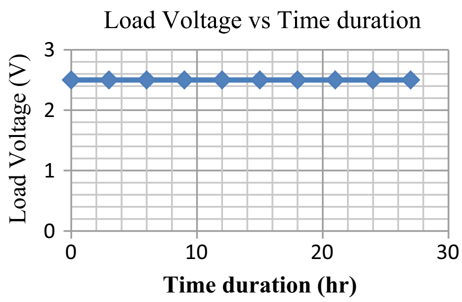


Fig. 4 Load voltage versus time duration

decreases up to 22 h and then after it was constant up to 27 h. Figure 6 shows the load current versus time duration curve. It is shown that the short circuit current was constant at 1.6 mA up to 15trs and then it decreases up to 22 h and then after it was constant up to 27 h.

Figure 7 shows the maximum power versus time duration curve. It is shown that the short circuit current was constant at 5.76 mW up to 15trs and then it increases up to 18 h and then after it decreases up to 22 h and then after it was almost constant up to 27 h. Figure 8 shows the maximum power versus time duration curve. It is shows the load power was same at 4 mW up to 15trs and then it increases up to 18 h and then after it decreases up to 22 h and then after it was almost constant up to 27 h.

It is shown from Fig. 9 that the internal resistance was almost constant up to 18 h and then it increases up to 1.88 Ω.

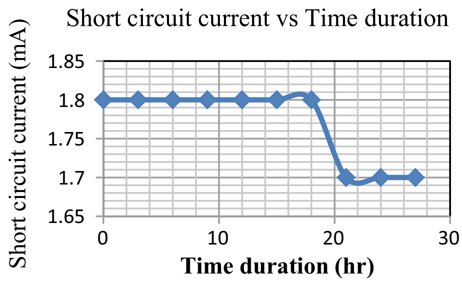


Fig. 5 Short circuit current versus time duration

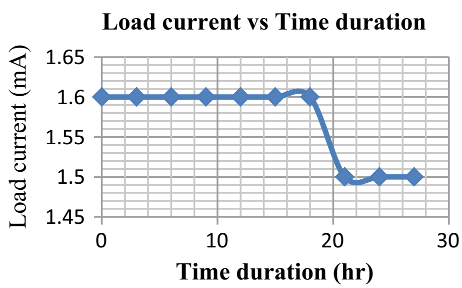


Fig. 6 Load current versus time duration

Fig. 7 Maximum power versus time duration

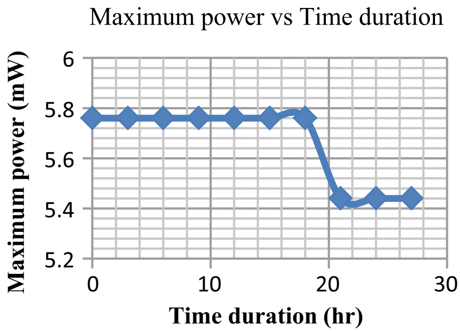


Fig. 8 Load power versus time duration

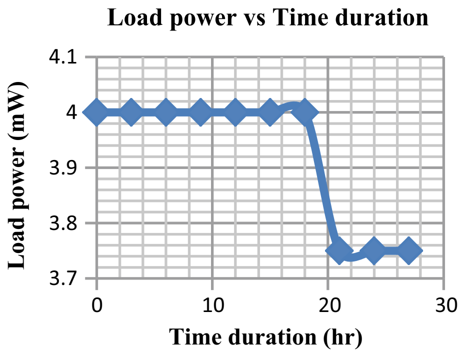
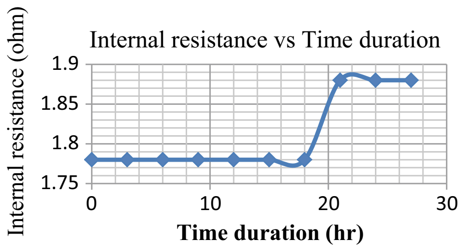


Fig. 9 Internal resistance versus time duration



3.2 Graphical Analysis of LED Bulb Lighting System Using Red Spinach (Amaranthus Dubius) Extract with $CuSO_4$

Table 2 shows that the performance of data for LED bulb lighting system using red spinach (*Amaranthus dubius*) extract with $CuSO_4$. The collected parameters were V_{oc}, V_L, I_{sc}, I_L, P_{max}, P_L and internal resistance.

Figure 10 shows that the open circuit voltage was 2.7 V which remains constant up to 27 h. Figure 11 shows that the load voltage was 2.4 V up to 27 h. It is found

Table 2 Data for LED bulb lighting system using red spinach (*Amaranthus dubius*) extract with $CuSO_4$

Time duration (hr)	V_{oc} (Open circuit voltage) (V)	V_L (Load voltage)(V)	I_{sc} (Short circuit current) (mA)	I_L (Load current) (mA)	Maximum power $P_{max} = V_{oc} I_{sc}$ (mW)	Load power $P_L = V_L I_L$ (mW)	Internal resistance, $r_{in} = \frac{V_{oc}}{I_{sc}}$ (Ω)
0	2.7	2.4	7.7	7.5	20.2	18.0	0.347
3	2.7	2.4	7.7	7.5	20.2	18.0	0.347
6	2.7	2.4	7.7	7.5	20.2	18.0	0.347
9	2.7	2.4	7.7	7.5	20.2	18.0	0.347
12	2.7	2.4	7.6	7.4	19.0	17.02	0.339
15	2.7	2.4	7.6	7.4	19.0	17.02	0.339
18	2.7	2.4	7.6	7.4	19.0	17.02	0.339
21	2.7	2.4	7.5	7.3	18.0	16.06	0.33
24	2.7	2.4	7.5	7.3	18.0	16.06	0.33
27	2.7	2.4	7.5	7.3	18.0	16.06	0.33

that after adding secondary salt as $CuSO_4$ 5 H_2O, the voltage has been decreased for both open circuit and load voltages.

Figure 12 shows the short circuit current versus time duration curve. It is shown that the short circuit current has been increased than the normal red spinach leaf extraction electro chemical cell. The short circuit current varies from 7.7 to 7.5 mA.

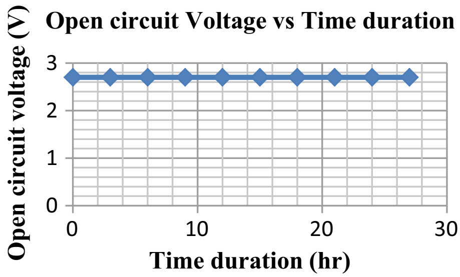


Fig. 10 Open circuit voltage versus time duration

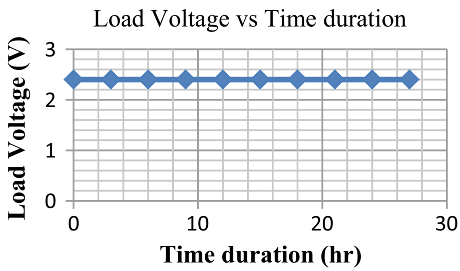


Fig. 11 Load Voltage versus time duration

Whereas for the normal red spinach leaf extraction electro chemical cell short circuit current varies from 1.8 to 1.7 mA. Figure 13 shows the Load current versus time duration curve. It varies from 7.5 to 7.3 mA. Whereas for the normal red spinach leaf extraction electro chemical cell short circuit current varies from 1.6 to 1.5 mA.

Figure 14 shows the maximum power versus time duration curve. It is shown that the maximum power has been increased than the normal red spinach leaf extraction electro chemical cell. The maximum power varies from 20.2 to 18.0 mW. Whereas for the normal red spinach leaf extraction electro chemical cell maximum power varies from 5.76 to 5.44 mW. Figure 15 shows the Load power versus time duration curve. It varies from 18 to 16.06 mW. Whereas for the normal red spinach leaf extract electro chemical cell short circuit current varies from 4.00 to 3.75 mW.

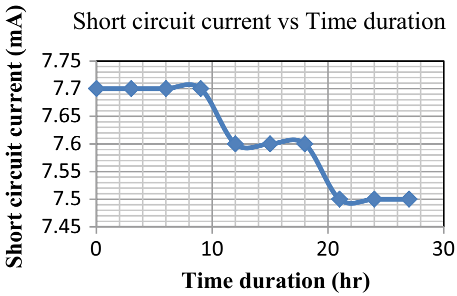


Fig. 12 Short circuit current versus time duration

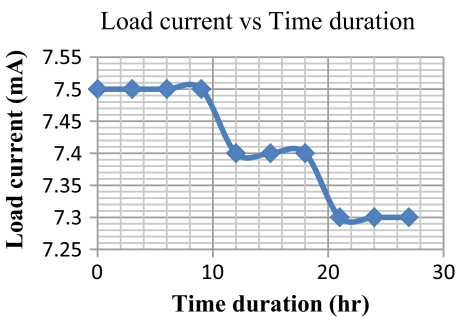


Fig. 13 Load current versus time duration

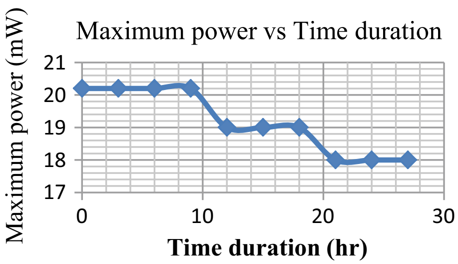


Fig. 14 Maximum power versus time duration

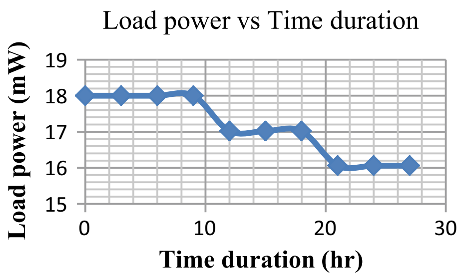


Fig. 15 Load power versus Time Duration

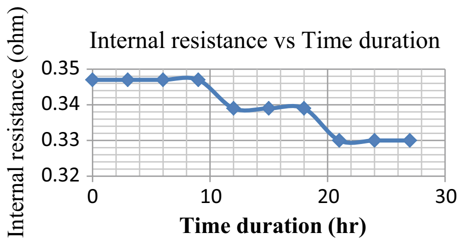


Fig. 16 Internal resistance versus time duration

It is shown from Fig. 16 that the Internal resistance versus Time duration curve. It is shown that it varies from 0.47 to 0.33 Ω. Whereas for the normal red spinach leaf extraction electro chemical cell maximum power varies from 1.78 to 1.88 Ω. It is found that the Internal resistance decreases and the power also increases after using Copper sulphate and the current also increases.

4 Conclusions

In this research work, plants leaves have been used as a renewable energy source. It has been presented a method of electricity production using red spinach leaf extract. Previously, different vegetative, fruits and leaves have been used for power production. But red spinach is different from them. It can be used for power production at remote areas all over the world.

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