



A Study on Zn/Cu and Zn/RGO based Arum Leaf (AL) Electrochemical Cell

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ABSTRACT

A bio-voltaic cell (BVC) has been designed and developed using various types of electrodes and plant extract electrolytes. Various parameters such as open circuit voltage, V_{oc} (V), short circuit current, I_{sc} (mA), power (W), have been studied using synthesised Ag Nanoparticles (NPs) to check the performances of BVC. Arum Leaf (AL) helped to produce electricity. Apart from this, various effects such effect of Arum Leaf (AL) scientific name *Colocasia Esculenta*(C.E) living plant living plant, effect of AL extract, effect of secondary salt, effect of Ag NPs, effect of Reduced Graphene Oxide (RGO) adsorbed paper electrode, effect of RGO-Ag NPs nanocomposite and cell potential of various electrodes have been studied to investigate the performance of BVC. On the other hand, silver nanoparticles (Ag NPs) have been synthesized through an eco-friendly, cost-effective green approach by using AL extract, and the power generation activity of BVC AL has been investigated with these Ag NPs.

Keyword: Arum Leaf (AL), Zn/Cu electrodes, Zn/RGO electrodes, electrochemical cell, open circuit voltage(V_{oc}), short circuit current(I_{sc}), Maximum power (W).

1. Introduction

Electricity generation from AL extract using various electrode in Bio-Voltaic Cell (BVC) have been studied very carefully^[1-2]. Various organic compound; especially Apigenin, Luteonin, Anthocyanidin and Cyanidin -3- glucoside are present in AL extract^[3-5]. All of existing compounds in AL are phenolic compounds and form resonance structure. As a result hydrogen ion (H^+) release from compounds and pH range lies between 4.50 to 5.75. In this BVC Zn is used as an anode and Cu is used as a cathode^[6]. AL extract is used as an electrolyte. Using secondary salt ($CuSO_4 \cdot 5H_2O$), various NPs and RGO adsorbed paper electrode; voltage, current and power can be increased from existing state^[7]. Three parameters such as open circuit voltage, V_{oc} (V), short circuit current, I_{sc} (mA) and power, $P_{max} = V_{oc} \times I_{sc}$ (W) are measured to check the performance analysing of BVC using five types of electrode such

as Zn/Cu (1 cm²), Zn/RGO (2 hrs), Zn/RGO (24 hrs), Zn/RGO (2 hrs) wrapped Ag NPs and Zn/RGO (6 hrs) wrapped Ag NPs two types of electrolyte such as PKL and AL electrolyte.

2. Methodology

2(a) Arum leaf extract preparation



Fig.1: Preparation of Arum leaf extract

The electrolyte such as AL extract including Ag NPs have been applied in bio-voltaic cell. AL has been taken first then it has been chopped. Thereafter it has been blended in presence of water (AL: H₂O = 1:1) by a blender machine. Then it has been filtered. This extract has been applied in bio-voltaic cell to generate electricity. Once a mixture is prepared for producing electricity. It serves the purpose for 6 months continuously. Beside this, a byproduct can be produced as bio-fertilizer (shown in Fig.1).

2(b) Zn/RGO Electrode Preparation

Two types of electrodes have been applied in bio-voltaic cell such as Zn/Cu and Zn/RGO, Where RGO means Reduced Grapheme Oxide. Here RGO is a paper electrode. It has been prepared in our own laboratory. The Zn/Cu based paper electrodes have been used for different 2 cases. The 2 different cases are: (i) Zn/Cu electrode using AL extract. (ii) Zn/Cu electrode using AL extract and AgNPs. The Zn/RGO based adsorbed paper electrodes have been used for different 4 cases. The different cases are: (i) Zn/RGO adsorbed paper electrode for 3 hrs time duration using AL extract. (ii) Zn/RGO adsorbed paper electrode for 3 hrs time duration using AL extract and AgNPs. (iii) Zn/RGO adsorbed paper electrode for 6 hrs time duration using AL extract. (iv) Zn/RGO adsorbed paper electrode for 6 hrs time duration using AL extract and AgNPs.

2(c) Zn/Cu Electrode Preparation

E-Cu58 Copper foil purchased from Jiangsu Xiguan Metal Product Co. Ltd. China and Zinc sheet purchased from Ing Co. Ltd. Japan. Then it has been scissored to prepare electrode. Various parameters of electrode has been prepared for various types of electrode.



Fig. 2: Zn/Cu electrode preparation for bio-voltaic cell

2(d) Reduced Graphene Oxide (RGO) Preparation

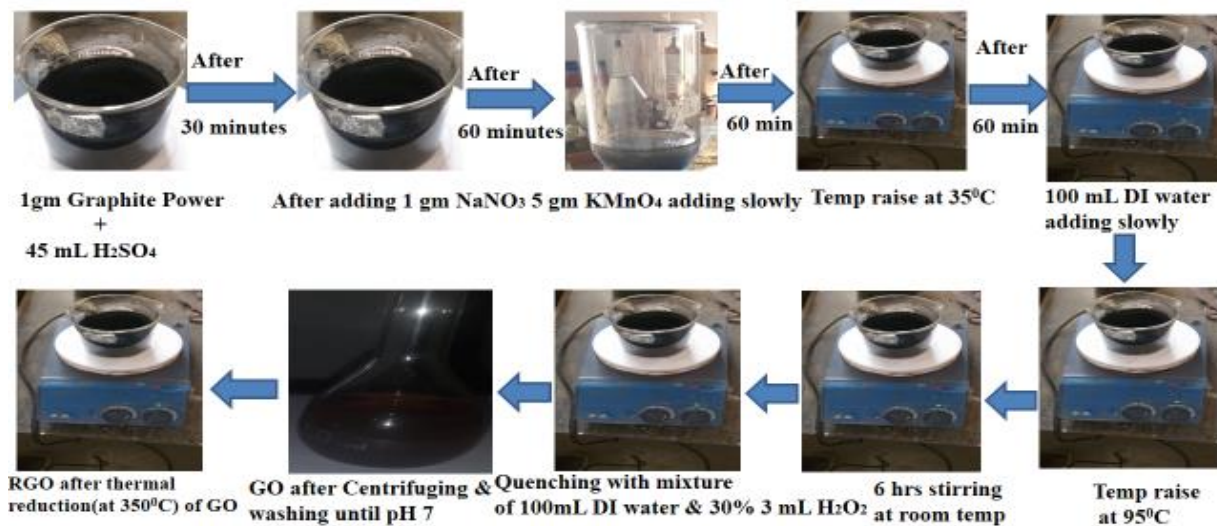


Fig.3: Reduced Graphene Oxide (RGO) Preparation using Hummers’ method

RGO have been prepared using Hummers’ method. At first 1gm graphite powder with 45 mL H₂SO₄ taken in a beaker. After 30 minutes 1 gm NaNO₃ has been added. There after 60 minutes 5gm KMnO₄ has been added slowly then the temperature has been increased up to 35°C using a magnetic stirrer with hot plate. After 60 minutes 100 mL DI water has been added slowly then temperature has been increased up to 95°C by 6 hours stirred at room temperature. Then quenched with mixture of 100 mL DI water and 30% 3 mL H₂O₂. After centrifuging and washing until pH 7 graphene oxide (GO) prepared. Finally, after thermal reducing at 350°C of GO to reduced graphene oxide (RGO) have been prepared.

2(e) RGO adsorbed paper electrode preparation

RGO adsorbed paper electrode has been prepared by the following method:

At first RGO adsorbed on cellulose paper using auto suction pump. After 3 hours adsorption it turned into brown color and then it made as an electrode according to specific measurement. Finally this electrode apply in the bio-voltaic cell in the substitute of Cu with Zn electrode.

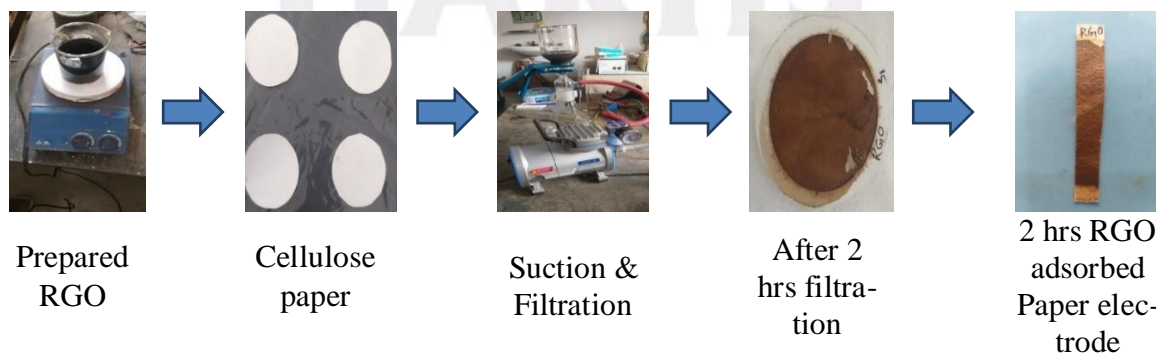


Fig.4: Two hours RGO adsorbed paper electrode preparation

2(f) RGO adsorbed paper electrode kept under Ag NPs

It has been prepared two hours RGO adsorbed paper electrode kept under Ag NPs solution then it form RGO-Ag Nano composite paper electrode. Finally RGO-Ag Nano composite paper electrode applied on cell in the substitute of Cu with Zn electrode.

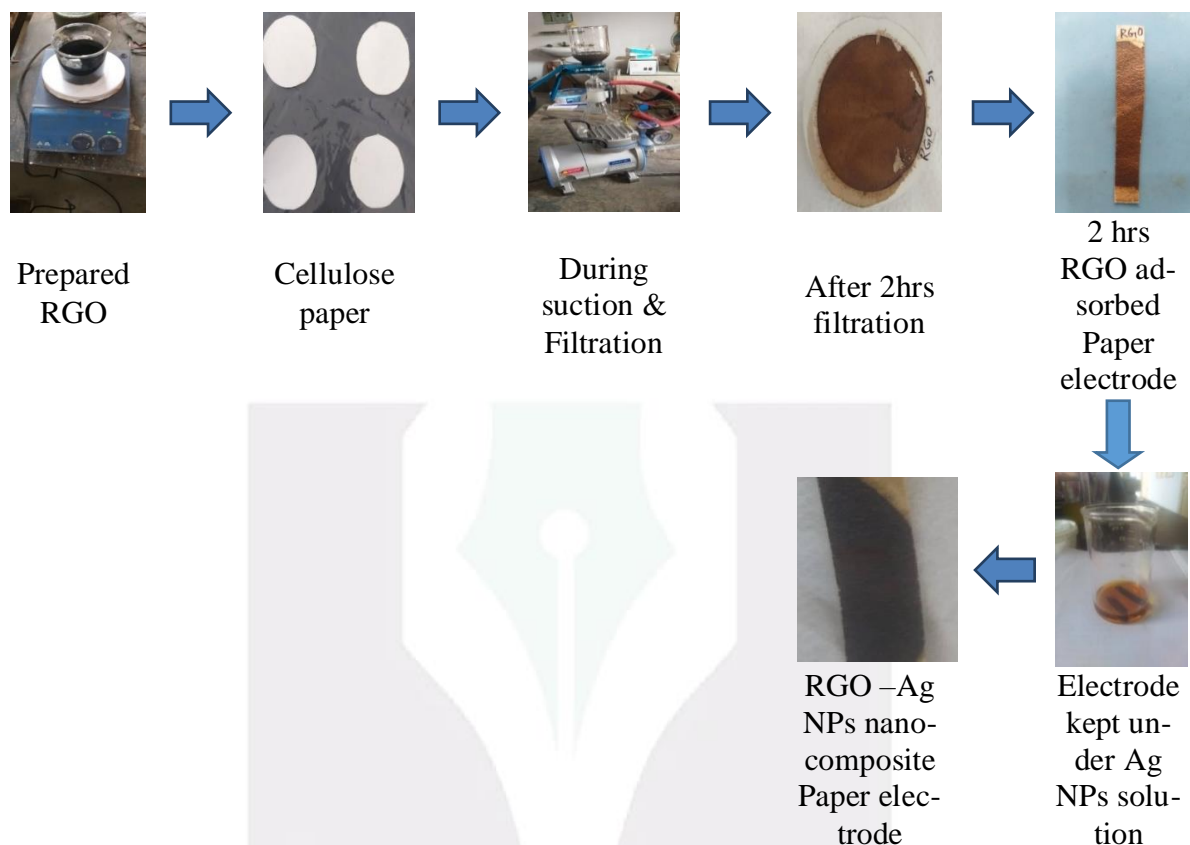


Fig.5: Ag NPs wrapped two hours RGO adsorbed paper electrode preparation

2(g) Synthesis of Ag Nanoparticle from Arum Leaf (AL)

C. esculenta leaves which is known as Arum Leaf (AL) were collected from Jagannath University campus, Bangladesh. 20g of leaves were taken and appropriately washed with pure water to remove the unwanted particles. Thereafter, the leaves were washed with Deionized (DI) water three times and chopped to blend to make a fine paste. 100 mL of DI water were mixed with leaves paste and placed on a hot plate at 60°C for one hour. The hot solution was kept aside to cool. The solution was filtered twice with Whatman41 and Whatman 42 filter paper then the filtrated extract solution was kept in a refrigerator at 4°C before use. A pure AgNO_3 precursor purchased from Sigma Aldrich has been used in this experiment. Then 5 mL AL extract solution was added to the 1mM 45 mL AgNO_3 . After an hour, the color of mixture had been changing that was observed. The colorless mixture solution was becoming brownish with the time, which indicated the formation of Ag NPs. To complete the reduction of Ag^+ to Ag^0 the solution was kept at room temperature for the next couple of days in a dark chamber. The color change from light yellow to dark brown affirms the reduction of Ag^+ and the formation of Ag NPs. The fabrication steps are shown in Fig.6.

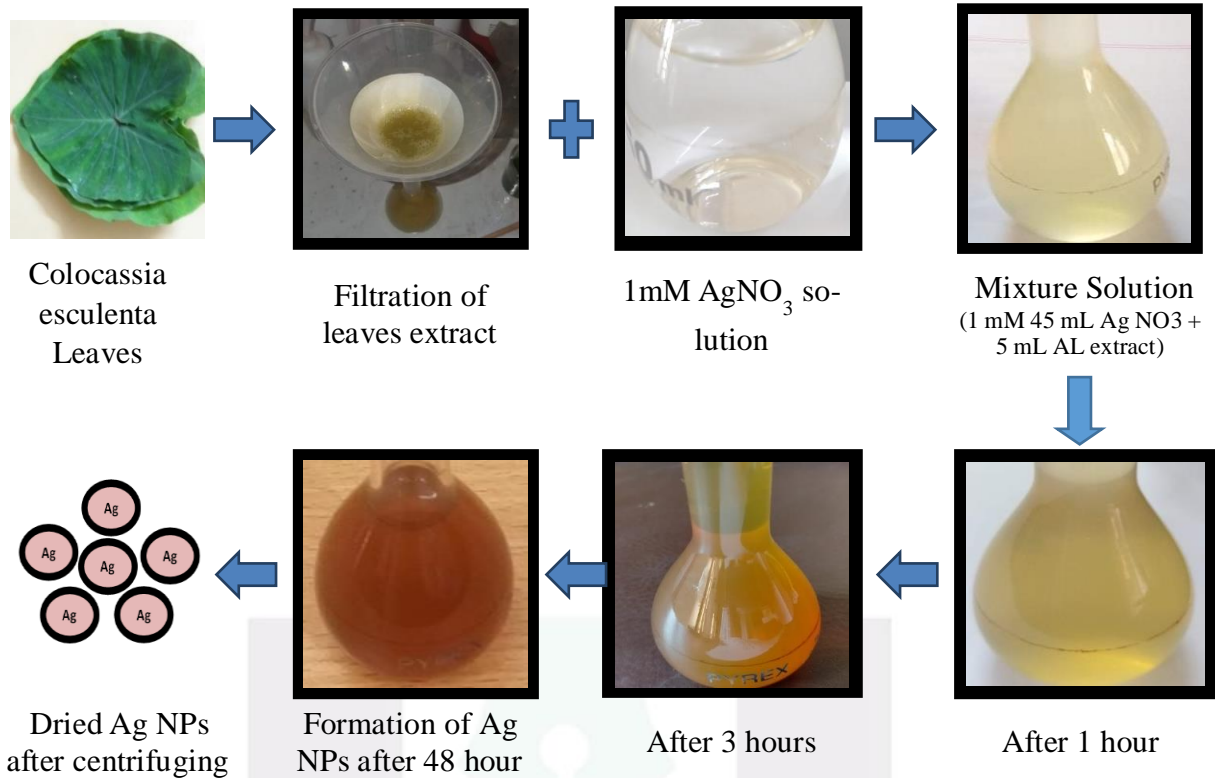


Fig.6: Synthesis of Ag NPs using AL extract

3. Results and Discussion

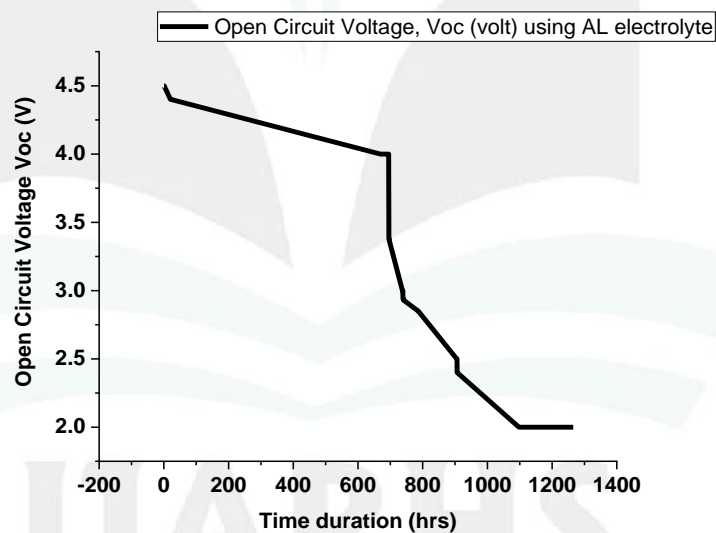


Fig.7: Variation of Voc (V) with time duration (hr)

Fig. 7 shows the open circuit voltage, V_{oc} (V) of BVC using AL extract electrolyte. At first open circuit voltage, V_{oc} (V) rapidly decrease for a while. Because, the independent function time duration range was very high with the dependent function open circuit voltage, V_{oc} (V) range was very low. That is why from the graph it is shown the open circuit voltage, V_{oc} (V) decreases very fast. That means, only 0.2 Volt reduced covering 45 hours. The Fig.7 also shows that at first open circuit voltage, V_{oc} (V) rapidly decreases from 4.54 (V) to 4.3 (V) within 10 hour. Then it decreases from 4.3 (V) to 4.00 (V) very slowly. But it abruptly decreases from 4.00 (V) to 3.00 (V) covering 100 hours. Again, it slowly decreases from 3.00 (V) to 2.50 (V) and it changes from 2.51 (V) to 2.00 (V) in a steady way. Finally it changes almost constantly from 2.00 (V) to 2.10 (V).

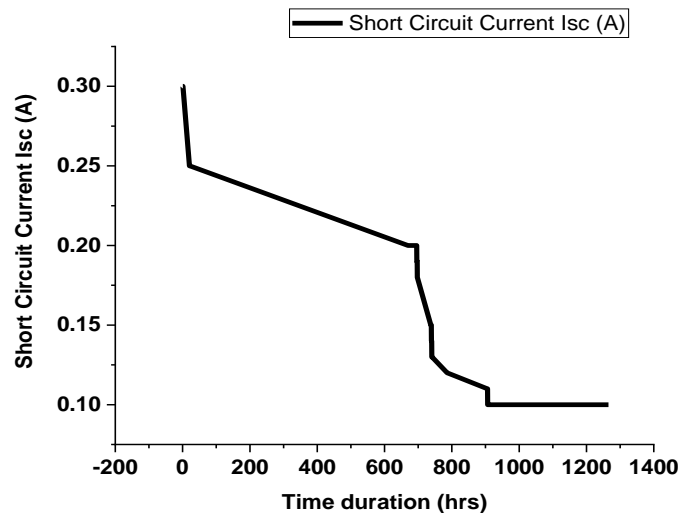


Fig.8: Variation of I_{sc} (A) with time duration (hr).

Fig.8 shows the short circuit current, I_{sc} (A) of BVC using AL extract electrolyte. At first short circuit current, I_{sc} (A) rapidly decrease for a while. Because, the independent function time duration range was very high with the dependent function short circuit current, I_{sc} (A) range was very low. That is why from the graph it is shown the short circuit current, I_{sc} (A) decreases very fast. That means, only 0.75 (A) reduced covering 48 hours. Fig.8 also shows that short circuit current falls down sharply into four phases. At first from 0.30(A) to 0.25 (A) decrease very sharply within 10 hours then it decrease very slowly from 0.25 (A) to 0.20 (A) very slowly within 700 hours. Then it decreases very fast from 0.20 (A) to 0.14 (A). Then again it falls down sharply into two phases; from 0.14 (A) to 0.12 (A) and from 0.12 (A) to 0.10 (A) respectively. Finally it changes very steadily from 0.10 (A).

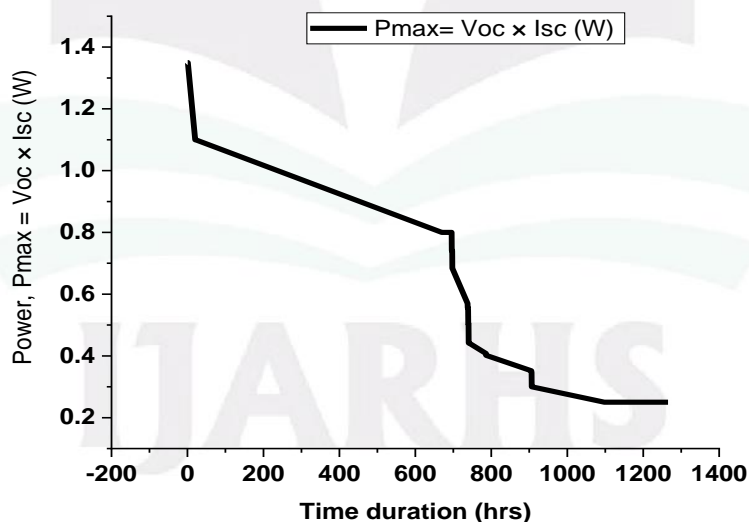


Fig. 9: Variation of power (W) with time duration (hr)

Fig. 9 shows the power $P_{max} = V_{oc} \times I_{sc}$ (W) of BVC using AL extract electrolyte. At first power $P_{max} = V_{oc} \times I_{sc}$ (W) reduced rapidly. Because, when open circuit voltage, V_{oc} (V) and short circuit current, I_{sc} (A) reduced gradually then power $P_{max} = V_{oc} \times I_{sc}$ (W) reduced automatically. That is why from the graph it is shown that the power $P_{max} = V_{oc} \times I_{sc}$ (W) decreases very fast. That means, only 0.16 (W) reduced covering 42 hours. Fig.9 also shows that

power $P_{\max} = V_{oc} \times I_{sc}$ (W) falls down sharply from 1.35 (W) to 1.15 (W) within 20 hours. Then it steadily decreases from 1.15 (W) to 0.80 (W) covering 680 hours. Then again it falls down sharply into three phases; from 0.80 (W) to 0.43 (watt) and from 0.43 (W) to 0.33 (W) and 0.33 (W) to 0.29 (W) respectively within 200 hours. Finally it changes very steadily from 0.29 (W) to 0.520 (W) covering 478 hours. Silver nanoparticles have been applied in the BVC using Arum Leaf (AL) extract electrolyte and the impact of nanoparticles has been monitored. Four types of BVC have been designated with four different bio-electrolyte solutions.

Fig.10 shows the comparative analysis of electrical parameters for all cells. The open-circuit voltage, short circuit current, power and internal resistance of four cells are shown in Fig. 10 (a, b, c, d).

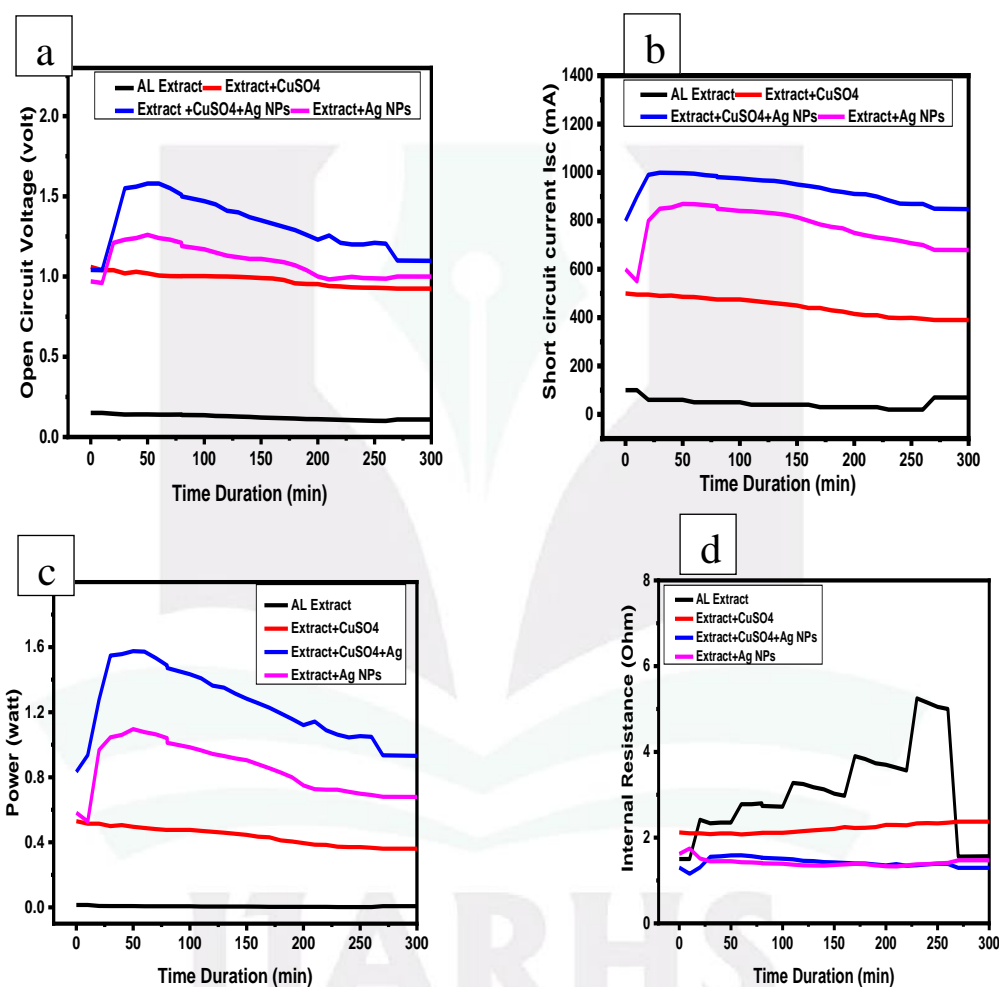


Fig. 10: Comparative analysis of (a) open-circuit voltage, (b) short circuit current, (c) power, and (d) internal resistance of four bio-electrochemical cells.

The open circuit voltage and short circuit current were significantly increased after using Ag NPs to extract electrolytes. The lowest values of voltage and current were found for only plant extract electrolyte-based cells. After using CuSO₄ with extract, the electrical parameters were increased due to the secondary salt effect. Moreover, the current and voltage were surprisingly increased after using silver nanoparticles in bio-electrolyte and the maximum electrical performances were recorded for this case. Since the current and voltage were dramatically enhanced in the presence of nanoparticles.

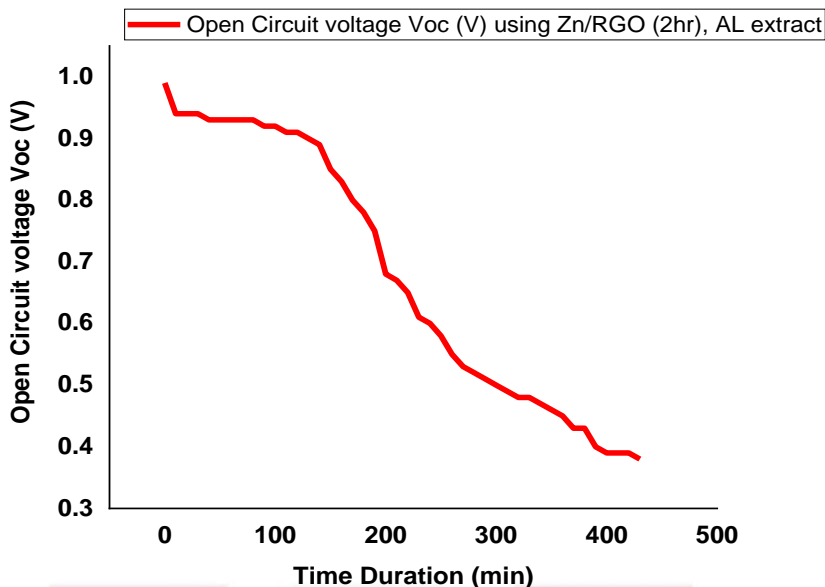


Fig. 11: Variation of V_{oc} (V) with time (min) using Zn/ RGO (2 hrs) electrode and AL electrolyte

Fig. 11 shows the variation of V_{oc} with the variation of time duration. It is shown that V_{oc} varies with time exponentially and the almost linearly.

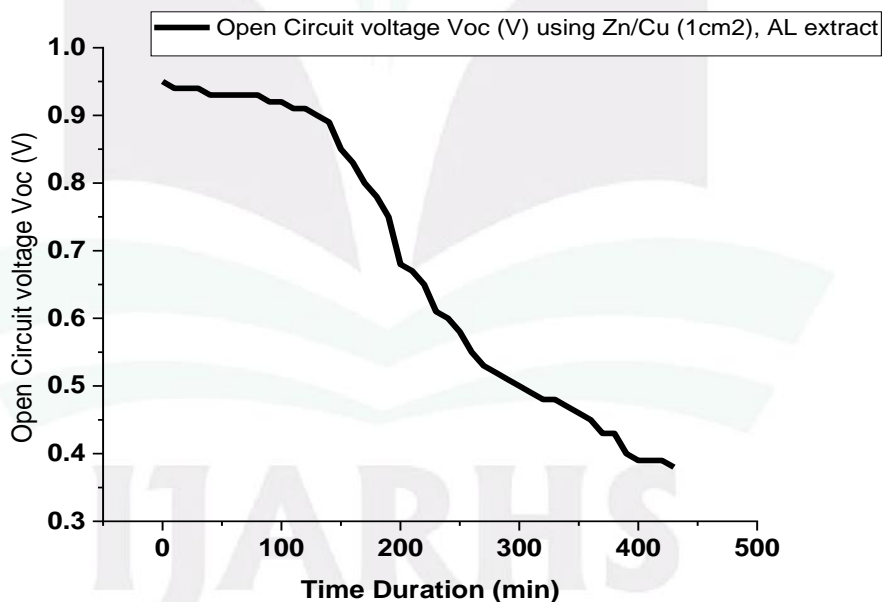


Fig.12: Variation of V_{oc} (V) with time (min) using Zn/Cu (1 cm²) electrode and AL electrolyte

Fig.12 shows the variation of V_{oc} with the variation of time duration. It is shown that V_{oc} varies with time exponentially and the almost linearly.

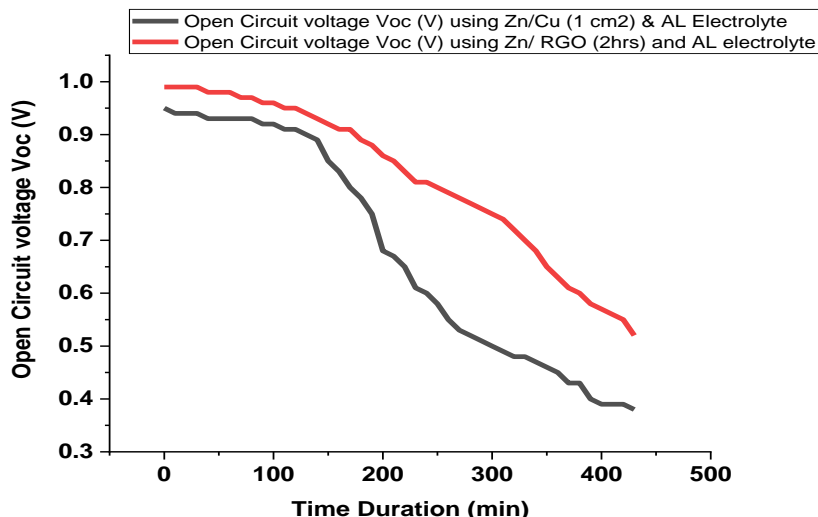


Fig. 13 : Variation of V_{oc} (V) with time (min) between Zn/Cu (1 cm²) & Zn/ RGO (2 hrs) electrode using AL electrolyte

Fig. 13 shows the open circuit voltage, V_{oc} (V) of BVC using Zn/Cu and Zn/ RGO (2 hrs) electrode with AL electrolyte. The open circuit voltage, V_{oc} (V) of BVC using Zn/ RGO (2 hrs) electrode is better performer than Zn/Cu electrode. Because, electrical conductivity of RGO is better than Cu which is consistent with the published result. Fig.13 also shows the performance of open circuit voltage, V_{oc} (V) using Zn/ RGO (3 hrs) electrode with AL electrolyte. The Fig.13 shows performance open circuit voltage, V_{oc} (V) using Zn/Cu (1 cm²) electrode with AL electrolyte. Fig. 13 shows that performance of open circuit voltage V_{oc} (V) using Zn/ RGO (2 hrs) electrode is 0.4 V greater than Zn/Cu (1 cm²) electrode with AL electrolyte.

Table1: Comparative study of Zn/Cu (1 cm²) and Zn/RGO (2 hrs) electrode performance in BVC with AL electrolyte

No.	Performance parameters of BVC	Type of electrolyte	Type of electrodes	
			Zn/Cu (1 cm ²)	Zn/ RGO
1	Open circuit voltage, V_{oc} (V)	AL	0.95 V	0.99 V
2	Short circuit current, I_{sc} (mA)	AL	110 mA	215 mA
3	Power, $P_{max} = V_{oc} \times I_{sc}$ (W)	AL	0.10 W	0.21 W

It is shown (Table-1) the summary of the performances of the AL based bio-voltaic cell. It is shown that the performances of RGO is better than the Cu electrode.

4. Conclusion

It is clear from the above Table- 1 that BVC developed using Zn/ RGO (2 hrs) electrode and Arum leaf (AL) extract electrolyte showed better performance than that of the BVC developed using Zn/Cu (1 cm²) electrode and AL extract electrolyte. Because, electrical conductivity of RGO adsorbed paper electrode is better than Cu electrode which is the consistent with the published result. There are several advantages for using RGO paper electrode instead of Cu electrode. RGO paper electrode is more economic than the Cu electrode.

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