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Comparative Analysis on Bioelectricity Production from Water Hyacinth, Cow Dung and Their Mixture Using a Multi-Chambered Biomass Battery

K. Sudhakar
Department of Energy, M.A.N.I.T.
Bhopal 462051, Madhya Pradesh, India

R. Ananthakrishnan
Department of Energy, M.A.N.I.T.
Bhopal 462051, Madhya Pradesh, India

Abhishek Goyal
Department of Energy, M.A.N.I.T.
Bhopal 462051, Madhya Pradesh, India

***Abstract* - This paper compares the biomass battery output for different biomass substrates. This approach of producing electricity can be utilized to meet the lighting requirements of rural household using available biomass. This is done via anaerobic digestion of the biomass and power generation driven by the ions produced henceforth. Bioelectricity generated from dry Water Hyacinth in 3:2 ratio with water, Cow Dung in 1:9 and 1:4 ratio with water and a mixture of Water Hyacinth, Cow Dung and water in the ratio 3:3:4, was evaluated in a multi-chambered biomass battery . This battery uses zinc plate and graphite electrodes to obtain bioelectricity from the substrate. The output voltage, current, internal resistance, power density and their feasibility was compared for different substrates.**

***Keywords* – Bioelectricity, Biomass Battery, Water Hyacinth.**

I. INTRODUCTION

Biomass energy utilization has gained particular interest in recent years due to the progressive depletion of conventional fossil fuels, which calls for an increased use of renewable energy sources. Biomass energy is more economical to produce and it provides more energy than other energy forms.[1] Suggests that Bio-energy is now accepted as having the potential to provide a major part of the projected renewable energy provisions of the future. [2-4]. In this direction, microbial fuel cells technology for bioelectricity generation is being studied extensively. [5-10]. It results from the conversion of chemical energy into electrical energy. In most organisms bioelectric potentials vary in strength from one to several hundred millivolts. The most important difference between bioelectric currents in living organisms and the type of electric current used to produce light, heat, or power is that a bioelectrical current is a flow of ions (atoms or molecules carrying an electric charge), while standard electricity is a movement of electrons. Bioelectricity can be generated when two electrodes with different potential are immersed in biomass. Bioelectricity is flow due to flow of movement of ions. Ions are generally flow from lower potential to higher potential. The basic chemical reaction involved in the biodegradation process is as follows:

Anode: $C_2H_4O_2 + 2H_2O \rightarrow 2CO_2 + 8\,e^- + 8\,H$

Cathode: $8\,H^+ + 8\,e^- \rightarrow 4\,H_2$

Water hyacinth and Cow dung has the potential to serve as a means to generate electricity in many remote villages. The provision of electricity in our remote villages continues to be a pipe dream. Several slum areas in and near Bhopal City are deprived of electricity. People residing in these places have inadequate lighting solutions. In these areas we have found average of 2 cows in every house. So the cow dung is available in plenty. Bhopal City is known for its lakes and water hyacinth also known as Jal Kumbhi is present in plethora. Biomass battery may be the best and durable lighting solution for villagers. The ultimate aim of this work is to provide a renewable solution for the lighting problems in slums.

The biomass battery is a new technology in which microorganisms produce electricity directly from biodegradable material. Two goals are achieved at the same time: energy storage and electricity production. Biomass battery has an advantage over other electricity production methods because of their high efficiency. Following the principle of a chemical fuel cell, energy is converted to electricity, efficiently and free of harmful end products. Biomass battery uses zinc plate and graphite electrodes to convert the substrate into electricity through biological process. Due to the microbial action and biological reactions voltage difference is obtained at the two terminals. This output is used to power LED lamp for lighting. Graphite plate acts as positive electrode and Zinc plate as negative electrode of battery. Salt was added to the mixture of cow dung and water (ratio 1:4), to reduce its internal resistance and increase its conductivity. The aim of present study was to investigate the possibility of electricity generation from water hyacinth and its mixture with cow dung. To our best of knowledge it is for the first time that water hyacinth is reported to serve as energy generation and storage fuel in biomass battery.

II. EXPERIMENTAL

2.1 Biomass Battery Assembly

A plastic container having six chambers has been used. Every section comprises of a small grid. These six grids are placed in series. Each grid comprises of seven pair of electrodes placed in parallel as shown in Fig.I. In every grid the graphite anode and zinc cathodes are placed in parallel .This parallel combination is used to strengthen the voltage output of a single grid and to increase the current of the whole setup. Whole setup of parallel grids is screwed to the container lid. This enables easy filling and emptying of the container. The connecting wires are connected to two output ports present at the outside of this lid. Output voltage can be obtained from these output ports. Space has been provided between the grids and bottom surface of the battery which allows uniform spreading of the biomass substrate.

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Fig.1. Grid Setup

2.2 Analytical Procedure

Water Hyacinth is dried and chopped and mixed with water in the ratio of 3:2. Cow Dung mix with water is made in two different ratios 1:4 and 1:9. In the concentrated mix, 3 tablespoons of salt were added. Another substrate constitutes of Cow dung, chopped water hyacinth and water mixed in the ratio 3:3:4. All the four different substrates are introduced separately in the multi-chambered biomass battery. Each compartment contains graphite and zinc plate as electrodes. Due to the microbial and biological reactions voltage difference is obtained between the two terminals. This is also known as Bioelectricity**.** Fig. II shows the experimental setup.


Fig.2. Photograph of the Experimental Setup

Table I : Specifications

Substrates	Cow Dung, Water Hyacinth
Anode and cathode material	Graphite plate & zinc plate
Surface area of each plate of electrodes	35 (sq. cm)
Total surface area of zinc plate	3360 cm^2
Feeding nature (L/cycle) Batch	0.75

2.3 Analysis

Current (I), potential (V) and internal resistance (R) measurements were recorded using digital multi-meter (RISH Multi 15S). Power (W) was calculated using the equation P=IV, where I is in amperes and V is in mV. Power density (W/m^2) was calculated by dividing the obtained power with the surface area (sq. m) of the battery. The biomass battery was continuously monitored during experiment and readings were taken for 28 days, inoculation time was considered as day 0. The output voltage, current, internal resistance, power density and are compared for different substrates.

III. Results & Discussion

The current generation was instantaneous and there is no delay period. Consistent decrease in voltage and power was observed with the exhaustion of time(Table II, Table III) accounting for a maximum voltage output in the initial period which was 3.69V for WH(Water Hyacinth), 3.71V for CD 1:4 (Cow Dung 1:4), 3.65V for CD 1:9 (Cow Dung 1:9) and 3.86V for Mix (cow dung + water hyacinth). The Maximum Power Density obtained for WH was $0.153W/m^2$and for Mix was $0.151W/m^2$. The highest power density was obtained for CD 1:4 which was $0.253W/m^2$.The voltage output for CD 1:4 was the most stable among all the substrates. A 3V light source can be illuminated by WH for 2 weeks, 3 weeks by CD 1:9 and Mix and for 4 weeks by CD 1:4 (Fig. III). The power output for WH, CD 1:9 and Mix gradually declined in the initial period and drastically fell in the later stages (Fig. IV). Experimental data revealed the feasibility of consistent power generation from water hyacinth for about 2 weeks and from Mix for about 3 weeks. With this output LED lamps (3 volt) can be illuminated for about 15-28 days or more without changing the substrate. However, the performance and stabilization tendency of CD 1:4 was found to be best among all (Figure V). The internal resistance of CD 1:4 which was mixed with salt, which resulted in reduction of internal resistance by$1/10^{th}$ (Table IV).

Table II. Voltage, Current, Power and Power density of water hyacinth (3:2) and Cow dung (1:4)

Day	Water Hyacinth (3:2)				Cow Dung 1:4			
	V	I(mA)	P(W)	PD(W/m^2)	V	I(mA)	P(W)	PD(W/m^2)
1	3.69	14	0.05166	0.15375	3.60	23	0.0828	0.246429
2	3.65	14	0.0511	0.152083	3.70	23	0.0851	0.253274
3	3.61	14	0.05054	0.150417	3.71	23	0.08533	0.253958
4	3.58	14	0.05012	0.149167	3.68	23	0.08464	0.251905
5	3.54	14	0.04956	0.1475	3.64	23	0.08372	0.249167
6	3.51	13	0.04563	0.135804	3.62	23	0.08326	0.247798
7	3.47	13	0.04511	0.134256	3.60	22	0.0792	0.235714
8	3.42	14	0.04788	0.1425	3.68	22	0.08096	0.240952
9	3.36	14	0.04704	0.14	3.54	22	0.07788	0.231786
10	3.28	14	0.04592	0.136667	3.49	23	0.08027	0.238899
11	3.25	14	0.0455	0.135417	3.45	22	0.0759	0.225893
12	3.19	14	0.04466	0.132917	3.55	22	0.0781	0.23244
13	3.13	14	0.04382	0.130417	3.60	22	0.0792	0.235714
14	3.08	14	0.04312	0.128333	3.68	22	0.08096	0.240952
15	2.98	13	0.03874	0.115298	3.62	22	0.07964	0.237024
16	2.91	13	0.03783	0.112589	3.74	21	0.07854	0.23375
17	2.86	13	0.03718	0.110655	3.80	21	0.0798	0.2375
18	2.75	13	0.03575	0.106399	3.68	22	0.08096	0.240952
19	2.60	12	0.0312	0.092857	3.47	21	0.07287	0.216875
20	2.47	12	0.02964	0.088214	3.42	21	0.07182	0.21375
21	2.29	12	0.02748	0.081786	3.31	21	0.06951	0.206875
22	2.01	12	0.02412	0.071786	3.25	21	0.06825	0.203125
23	1.88	12	0.02256	0.067143	3.20	21	0.0672	0.2
24	1.74	12	0.02088	0.062143	3.14	21	0.06594	0.19625
25	1.62	12	0.01944	0.057857	3.13	21	0.06573	0.195625
26	1.39	12	0.01668	0.049643	3.09	21	0.06489	0.193125
27	1.14	12	0.01368	0.040714	3.04	21	0.06384	0.19
28	0.82	12	0.00984	0.029286	3.01	21	0.06321	0.188125

Table III: Voltage, Current, Power and Power density of Cow dung (1:9) and Cow dung+Water hyacinth mixture (3: 3:4)

Day	Cow Dung 1:9				Mixture Cow Dung + WH			
	V	I(mA)	P(W)	PD(W/m^2)	V	I(mA)	P(W)	PD(W/m^2)
1	3.65	14	0.0511	0.152083	3.86	12	0.04632	0.137857
2	3.62	14	0.05068	0.150833	3.81	12	0.04572	0.136071
3	3.60	14	0.0504	0.15	3.75	12	0.045	0.133929
4	3.61	14	0.05054	0.150417	3.72	13	0.04836	0.143929
5	3.64	14	0.05096	0.151667	3.49	12	0.04188	0.124643
6	3.59	13	0.04667	0.138899	3.43	12	0.04116	0.1225
7	3.57	13	0.04641	0.138125	3.37	12	0.04044	0.120357
8	3.54	14	0.04956	0.1475	3.34	13	0.04342	0.129226
9	3.50	14	0.049	0.145833	3.33	13	0.04329	0.128839
10	3.43	14	0.04802	0.142917	3.31	13	0.04303	0.128065

11	3.38	13	0.04394	0.130774	3.30	13	0.0429	0.127679
12	3.32	13	0.04316	0.128452	3.28	13	0.04264	0.126905
13	3.28	13	0.04264	0.126905	3.30	13	0.0429	0.127679
14	3.21	13	0.04173	0.124196	3.32	14	0.04648	0.138333
15	3.16	13	0.04108	0.122262	3.35	14	0.0469	0.139583
16	3.12	13	0.04056	0.120714	3.31	14	0.04634	0.137917
17	3.09	13	0.04017	0.119554	3.28	14	0.04592	0.136667
18	3.02	13	0.03926	0.116845	3.25	14	0.0455	0.135417
19	2.98	12	0.03576	0.106429	3.14	13	0.04082	0.121488
20	2.96	12	0.03552	0.105714	3.00	14	0.042	0.125
21	2.87	12	0.03444	0.1025	2.84	14	0.03976	0.118333
22	2.82	12	0.03384	0.100714	2.60	14	0.0364	0.108333
23	2.79	12	0.03348	0.099643	2.58	14	0.03612	0.1075
24	2.71	12	0.03252	0.096786	2.51	14	0.03514	0.104583
25	2.67	12	0.03204	0.095357	2.48	14	0.03472	0.103333
26	2.63	12	0.03156	0.093929	2.45	14	0.0343	0.102083
27	2.58	12	0.03096	0.092143	2.42	14	0.03388	0.100833
28	2.56	12	0.03072	0.091429	2.40	14	0.0336	0.1

Table IV : Internal Resistance of the Various Substrates

Substrate	Water Hyacinth	Mixture	Cow Dung 1:9	Cow Dung 1:4
Internal Resistance. MΩ	1.57	1.54	1.55	0.157

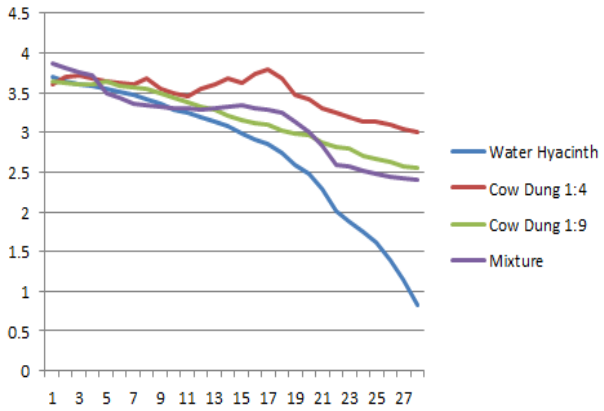

Fig.3. Voltage v/s Time for different substrates

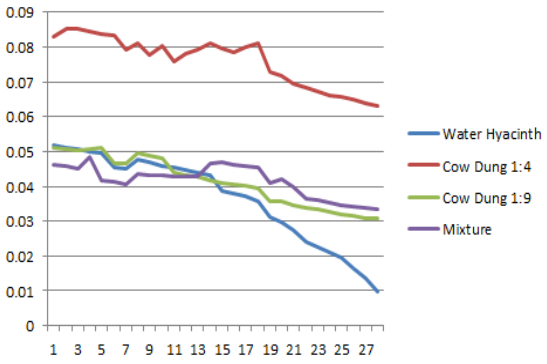

Fig. 4. Power v/s Time for different substrates

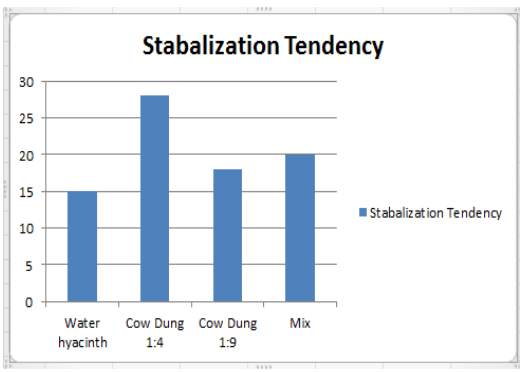

Fig.5. Stable Voltage in Days 4. Tables

IV. CONCLUSION

Under present investigation, bio-electricity was successfully generated with Water Hyacinth, Cow dung and their mixture as raw materials, using biomass battery technology. Water Hyacinth when used as the biomass substrate can power a 3V Light source for 2 weeks, after which the substrate will have to be replaced. The Water Hyacinth and Cow dung mixture is feasible for a greater period of time as compared to Water Hyacinth used separately. The maximum power density of the water hyacinth and cow dung mixture is higher as compared to the water hyacinth. The most viable option among all substrates is the concentrated cow dung (1:4). It can be used for 30 days as the substrate for the battery without changing the cow dung. Also when salt is added to the biomass, the internal resistance is reduced substantially ($1/10^{th}$in this case). Water hyacinth and cow dung when used as substrates for the biomass battery are cost-effective and environmentally sound and is sustainable solution for rural villages and slum areas. Water hyacinth can be used by the people residing near the lakes as a power source for lighting. The substrates can be used to generate electricity for rural household, making the technology more affordable for rural electrification.

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AUTHOR'S PROFILE

K. Sudhakar
obtained his B.E in Mechanical Engineering from Government College of Engg., Salem , M.Tech in Energy Management from School of Energy And Environmental Studies, Devi Ahilya University, Indore and Ph.D. from National Institute of Technology, Tiruchirapalli. He was awarded Senior Research Fellowship by DST and Young Scientist Award by MPCOST. His major research area include: Climate Change, Carbon Sequestration, Algae Bio-fuel, Solar Thermal, Solar PV, Hybrid Energy Systems, Microbial fuel cell and Energy Auditing. He is a Certified Energy Manager & Energy Auditor by BEE. He has been a keynote speaker and resource person at several International/National Conferences. He has published more than 50 research papers in International Journal and Conference. He is currently working as Assistant Professor in Energy Department, Maulana Azad National Institute of Technology, Bhopal. E-mail: sudha_k@sify.com

R. Ananthakrishnan
Final year, B.Tech, energy engineering, Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh. India He has interests in the field of Biomass Energy. He has also presented a paper at the technical festival of IIT-B.
Mr. Ananthakrishnan is currently the Chairman at the Indian Society for Technical Education Students Chapter MANIT.
E-mail: rakrishnan.iyer@gmail.com

Abhishek Goyal
Final year, B.Tech, energy engineering, Maulana Azad National Institute of Technology, Bhopal, Madhya Pradesh. India.
He has interests in the field of Solar, Wind and Biomass Energy. He is currently working in the cultivation of algae for biofuel. Mr. Goyal is currently a member of ISTE, SAE MANIT. E-mail: abhishek.goyal798@gmail.com