

# Development of plant extracts to produce electrolytes for electrochemical energy storage applications

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## Abstract

Increasing global energy and environmental challenges demand clean and sustainable energy sources to support modern society. In this work, some plant extracts were prepared to produce electrolyte solutions that can be utilized in electrochemical energy storage devices such as batteries, supercapacitors, and fuel cells. Results on the electric current and the electric potential of used plant extract-based electrolytes in electrochemical cells were presented and compared to electrolytes formed with salted water and hydrochloric acid solutions.

**Keywords:** Plant Extracts, Electrolytes, Electrochemical Cells, Energy Storage

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## I. INTRODUCTION

The search for ecological and sustainable energy storage systems must continue to address the limited availability of fossil fuels and their negative environmental impact. Sources of green energy are wind, ocean, photovoltaic cells, and plant energy [1-3]. Electrochemical energy storage devices that are environmentally friendly and sustainable are key to addressing the problem of limited energy resources and pollution. Advances in electrolytes have spurred the development of electrochemical energy storage devices for decades. Aqueous electrolyte-based devices have received a lot of attention in various energy storage technologies and should belong to the next generation of "green" batteries due to their safe and environmentally friendly nature, as well as their affordability and ease of manufacture. The water's non-flammability makes it a safer and more environmentally friendly solvent than flammable organic electrolytes.

When using organic electrolytes, gas ignition and a flame cloud may occur due to overcharging and/or overheating, and the flammability of organic electrolytes may cause an explosion due to short circuits. Moreover, organic electrolytes always break down on the surface of active materials, resulting in the formation of a solid electrolyte interphase (SEI) and preventing charge transfer. Due to their high heat capacity and non-flammability, aqueous electrolytes can solve major safety issues. Second, aqueous solutions have two orders of magnitude higher ionic conductivity than non-aqueous solutions, which translates to higher throughput capacity and reversibility in batteries. Third, the salts used in aqueous electrolytic systems are generally less expensive, making them a cost-effective option. However, aqueous batteries, for example, face major challenges in their practical use due to their low energy density and poor cycle performance. Additionally, the narrow electrochemical stability window of water, 1.23 V in thermodynamic equilibrium, limits its use in high-voltage applications.

The harvesting of electricity produced by plants has also been used to conduct research on living plant energy. The Cu-Zn wire electrodes were used to perform a Galvanic cell reaction on Aloe vera leaves [4-6], as well as Cu-Fe, Al-Zn, and Cu-Al electrodes on other plants [7].

### 1.1 Materials and Experiments

#### 1.1.1 Plant Extracts based Electrolytes

Figure 1 shows some of the different plants such as Cinnamon, Artemisia, Thyme, Henna, Curcuma, and Haza which were investigated as sources of extracts for electrolytes.



**Fig.1.** Investigated plants for extracts

About 100g of a selected plant is dried, ground, and put in 300g of distilled water. The mix is then placed in the Soxhlet extractor (Fig.2).



**Fig.2.** Soxhlet extractor

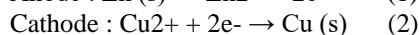
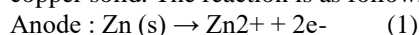
When the desired compound has limited solubility in a solvent and the impurities are insoluble in that solvent, Soxhlet is usually required. Simple filtration is used to separate the desired compound from insoluble materials if the desired compound has a high solubility in the solvent. The solid containing the desired compound is placed in the main chamber of the Soxhlet apparatus, inside a tube made of thick filter paper. The solvent is re-dissolved by heat where the solvent vapor flows through a distillation arm and into the chamber containing the solid to be extracted. The condenser ensures that any solvent vapor that drips onto the solid chamber is cooled. Slowly, the warm solvent is poured into the chamber containing the solid. Some of the desired substances dissolved in the warm solvent as a result of this procedure. When the Soxhlet chamber is almost full, a side siphon lever automatically empties the chamber, and the solvent is returned to the distillation flask. This cycle is left to repeat for 8 hours. A portion of the non-volatile compound is dissolved in the solvent during each cycle. The compound is concentrated in the distillation flask after several cycles. This system has the advantage of using a fixed amount of solvent that is recycled rather than passing several portions of warm solvent through the sample. After extraction, the solvent is removed with a rotary evaporator, and the extracted compound is released. The portion of the solid that has not been dissolved remains in the tube and is usually discarded.

### **1.1.2 Characterization of Plant Extracts-based Electrolytes**

Plant extracts were characterized with respect to their electrical conductivity, electrical potential, and temperature. The conductivity is measured using Jenway 4510 conductivity /TDS meter at different temperatures and different levels of viscosity. The data was collected automatically. Automatic range selection, calibration on standard solutions or direct cell constant entry, automatic temperature compensation, analog output, and an RS232 serial interface are just a few of the features.

### 1.1.3 Testing of Electrolytes in Galvanic Cells

The elaborated plant extract-based electrolyte is tested in a simple galvanic cell that was constructed for the purpose. The galvanic cell is also called a voltaic cell, it is an electrochemical device that generates electricity through spontaneous oxidation-reduction reactions at the anode and cathode electrodes of the cell. The reduction potential of copper and zinc are +0.34v and -0.76v, respectively. The zinc electrode releases electrons and becomes a Zn<sup>2+</sup> ion, while Cu<sup>2+</sup> in the plant extract receives electrons and the ion becomes copper solid. The reaction is as follows:



Copper and zinc electrodes were cut with a dimension of 4 cm × 2 cm, then connected with wires by soldering. After that, the electrodes were plunged into a selected plant extract-based electrolyte, and the electric potential and electrical current were measured. For comparison purposes, a reference cell will be made by using an electrolyte formed with salted water and hydrochloric acid solutions.

## II. RESULT AND DISCUSSION

Table 1 shows the different plants which were investigated to make extracts-based electrolytes for electrochemical galvanic cells. The values of electrical conductivity (CD) and PH are listed at room temperature. Among the studied plants, Haza plant extract provides the highest electrical conductivity of 256 μS at 29°C. Figure 2 shows the electrical measurement of the electrochemical cell working under the Haza electrolyte.

Table 1						
	Cinnamon القرفة	Artemisia الطرفاء	Thyme الأثل	Henna الحناء	Curcuma الكرم	Haza الحزا
CD (mS)	6.02 26C	6.36 25.C	39.2 26C	95.5 31C	101.8 25C	<b>256</b> 29C
PH	4.1 25C	10.5 30C	6.1 25 C	5.1 25.5C	7.2 22.5C	5.9 30C



Haza Electrolyte



Galvanic cell



Electrical measurements

**Fig.2.** Electrical measurement of the electrochemical cell

Table 2. a, b, and c) lists the electric current and potential values at different concentrations of NaCl, HCl, and plant extract Haza electrolytes, respectively. The galvanic current increases with the increase of the electrolyte concentration. However, the electric potential produced decreases slightly with the concentration of the electrolytes. At a concentration level of about 45g/L, the HCl electrolyte is much more efficient than the NaCl counterpart. The galvanic current due Haza electrolyte is still low compared to both HCl and NaCl

electrolytes. The concentration of the Haza electrolyte does influence the value of the galvanic current produced. The electric potential ranges from 0.65V – 0.82V, it is about the same value for all electrolytes for equal electrolyte concentration.

**Table 2.** Galvanic current and the electric potential of the electrochemical cell working under a) NaCl, b) HCl, and c) Haza electrolytes

<b>a)</b>			<b>b)</b>		
<b>NaCl electrolyte</b>			<b>HCl electrolyte</b>		
Concentration (g/L)	I (mA)	V (V)	Concentration (g/L)	I (mA)	V (V)
9.627	2.9	0.77	45.385	72.2	0.826
18.411	3.84	0.78	87.407	101.7	0.796
27.975	4.7	0.71	126.429	108.8	0.794
37.068	5.4	0.7	162.759	114.8	0.775
45.747	6.4	0.7	196.667	115.9	0.745

<b>c)</b>		
<b>Haza electrolyte</b>		
Concentration (g/L)	I (mA)	V (V)
300	1.5	0.65
160	1.45	0.65
112.5	1.4	0.68

To test this electrochemical cell in an external circuit connected to a load, such as a light-emitting diode (LED), which requires approx. 1.6V, use larger surface electrodes or mount multi-electrode cells in series to increase the chance of the LED lighting up. Larger electrodes require more Haza electrolyte to cover the surface of the electrodes.

### III. CONCLUSION

Plant extracts were successfully used to make green electrolyte solutions, which were then used in electrochemical cells. Results on the electric potential and current were presented, and they were compared with electrolytes formed with NaCl and HCl solutions. Haza extract is found suitable as a working electrolyte in an electrochemical cell. However, its produced galvanic current is still low compared to when using HCl or NaCl electrolytes. The concentration of the Haza electrolyte does influence the value of the galvanic current produced. The electric potential ranges from 0.65V – 0.82V, it is about the same value for all electrolytes with the same concentration of electrolytes.

To test this electrochemical cell in an external circuit connected to a load, which requires higher electric potential, it is recommended to use larger surface electrodes or mount multi-electrode cells in series. Larger electrodes require more Haza electrolyte to cover the surface of the electrodes. Another option is to let the Haza solution evaporate to obtain an electrolyte in the form of a paste having a much higher concentration. This way we plan to investigate the power efficiency of the electrochemical cell when operated using an optimized plant extract-based electrolyte.

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### **Authors contribution**

The manuscript was written with the contributions of all authors. All authors have approved the final version of the manuscript.

### **Conflict of interest**

The authors declare that they have no conflict of interest.

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