

A Comparative Study of Fruit Battery Voltages with Different Types of Fruits using Different Electrode Combinations

Deepa S¹, Joshy K George², Noel Joseph Gomez³, Sanju Sreedharan⁴, Uma N⁵

Department of Electrical and Electronics Engineering¹

Department of Basic Science and Humanities²

Department of Mechanical Engineering³

Department of Civil Engineering⁴

Department of Electronics and Communication Engineering⁵

SCMS School of Engineering and Technology, Karukutty, Ernakulam

Abstract: The objective of the present research on fruit batteries was to compare the voltage produced by different fruits with different electrode combinations, keeping the cathode material unchanged (copper). The electrode pairs selected for the purpose are copper-iron (Cu-Fe), copper-zinc (Cu-Zn) and copper-aluminium (Cu-Al). The fruit acted as an electrolytic medium providing continuity to complete the electrical circuit. The potential differences created by each electrode pair were measured using a multimeter. From the results obtained, it was evident that the different fruits produced different voltages. The nature of the fruit is an indisputable criterion which decides the fruit battery voltage. The most important and relevant observation was that there was an increase in the voltage with increase in reactivity (oxidizing tendency) of the anode material. This observation was found to be true for all fruit batteries which were subjected to investigation and the result obtained could easily be explained based upon the positions of electrode materials in the activity series or electrochemical series.

Keywords: Fruit Battery, Electrode Combination, Electric Potential, Electrochemical Cell

I. INTRODUCTION

Electricity is the most effective and convenient form of energy for usage in different applications [1]. An electrochemical cell or voltaic cell is a device which converts chemical energy produced by some spontaneous reactions into electrical energy. This is the principle on which modern batteries work. In an electrochemical cell, two different electrodes and an electrolyte are necessary for the generation of electric current.

Electricity can be generated from fruits, vegetables etc., by the above principle with the difference that the electrolyte of the battery will be the natural juice in fruit or vegetable. The fruit provides the electrolyte and terminals of the battery will be the electrodes that are inserted into the fruits [2]. Zinc (as anode) and copper (as cathode) are the commonly used electrode pairs in most of the electrochemical cells for this purpose and the acid content present in fruit or vegetables is the electrolyte.

1.1 Chemistry with Respect to Fruit Battery

Two different metals are used as the electrodes while the organic acids like citric acid, malic acid etc. present in fruit act as the electrolyte. For a spontaneous reaction to take place, a metal higher up in the electrochemical series should be selected as the anode and a metal lower in the series as the cathode. In the case of Zn-Cu combination, the anode is zinc (standard electrode potential, $E_{\text{Zn}}^0 = -0.76 \text{ V}$) and cathode is copper ($E_{\text{Cu}}^0 = +0.34 \text{ V}$)

$$\begin{aligned} E_{\text{cell}}^0 &= E_{\text{cathode}}^0 - E_{\text{anode}}^0 \\ &= E_{\text{Cu}}^0 - E_{\text{Zn}}^0 \\ &= 0.34 - (-0.76) = 1.10 \text{ V} \end{aligned}$$

Zinc is an active metal which has an oxidizing tendency, i.e. a tendency to convert to ionic form and liberate electrons (readily takes place in the presence of citric acid).

Anode reaction: $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$ (Oxidation)

Zn^{2+} ions enter the electrolyte during the reaction. The Cu cathode can attract electrons more than Zn. Therefore, the electrons on the Zn electrode flows to the Cu electrode through the external circuit. The active ingredient of organic acid is H^+ ions which are reduced to the H_2 gas by electrons received from Cu electrode [3,4].

Cathode reaction: $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ (Reduction)

Fig. 1 shows the schematic representation of the fruit battery with Zn-Cu electrode pair. On oxidation of Zn to Zn^{2+} ions, the electrons produced travel through the external circuit to copper cathode and produce electricity in the external circuit. The hydrogen molecules formed at the surface of Cu electrode bubble away as H_2 gas. The chemistry involved in the case of Cu-Fe and Cu-Al fruit batteries are similar, but with theoretical cell potential values of 0.78 V and 2 V respectively under standard conditions. ($E_{\text{Al}}^0 = -1.66 \text{ V}$ and $E_{\text{Fe}}^0 = -0.44 \text{ V}$)

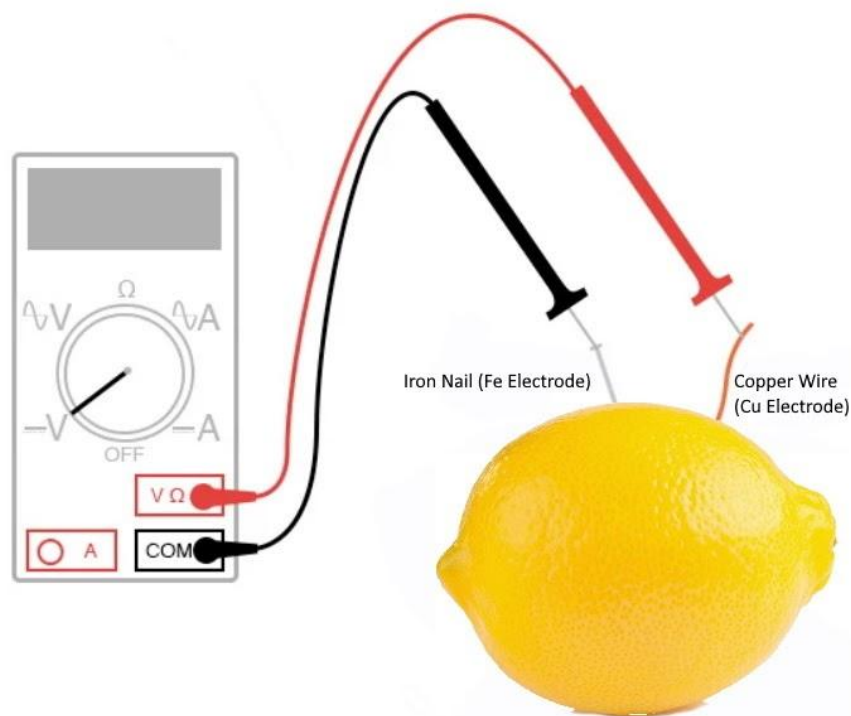


Figure 1: Schematic sketch of fruit battery

In the present study, five different fruits (apple, lemon, citrus Orange, star fruit, and tomato) were used for electricity generation and the voltage developed by each fruit is compared using three different combinations of metal electrodes viz. copper - iron (Cu-Fe), copper - zinc (Cu-Zn) & copper - aluminium (Cu-Al)

II. MATERIALS

Materials and equipment used are

1. Fruits : Apple, Lemon, Citrus Orange, Star fruit, Tomato
2. Electrodes : Copper, Zinc, Iron and Aluminium (3 mm dia wire)
3. Digital Multimeter
4. Connecting wire
5. Alligator clips

III. METHODOLOGY

The copper and zinc electrodes were washed thoroughly with detergents and hot water to remove impurities. After inserting the electrodes on fruit in a particular depth (30 mm) and at optimum distance (20 mm) from each other, the external circuit was completed by connecting anode to cathode using alligator clips and connecting wires. The voltage produced was noted using a multimeter, by connecting the terminals of the same to the copper and zinc electrode. The experimentation was repeated for other fruits and the readings were tabulated maintaining constant surface area of electrodes and electrode spacing. Then, the procedure was continued for the same fruits with Cu-Fe and Cu-Al electrode combinations. Fig. 2 shows the different fruits used and measurement of cell potential using digital multimeter.



Figure 2: Fruits used for the study and measurement of cell potential

IV. RESULTS AND DISCUSSION

The table 1 shows the voltages produced by the selected fruits using different electrode combinations. The cell potential values decrease from apple to tomato for all the three electrode combinations which can be attributed to the variations in pH, permeability etc. in the flesh of the fruit. Fig. 3 represents the voltage characteristics by the three electrode pairs for different fruits. The voltages produced by each fruit increases from left to right in every row in table 1. Precisely, the fruit battery voltages by different electrode pairs are in the increasing order Cu-Fe < Cu-Zn < Cu-Al. This experimental result is in agreement with (directly proportional to) the theoretical standard cell potential values predicted by the equation $E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0$

Fruits	Cell Potential (V)		
	Cu-Fe electrode	Cu-Zn electrode	Cu-Al electrode
Apple	0.63	0.82	1.1
Lemon	0.59	0.78	1.01
Citrus Orange	0.55	0.69	0.89
Star fruit	0.52	0.65	0.88
Tomato	0.5	0.58	0.81

Table 1: Volts measured for different fruit batteries using different electrode combinations

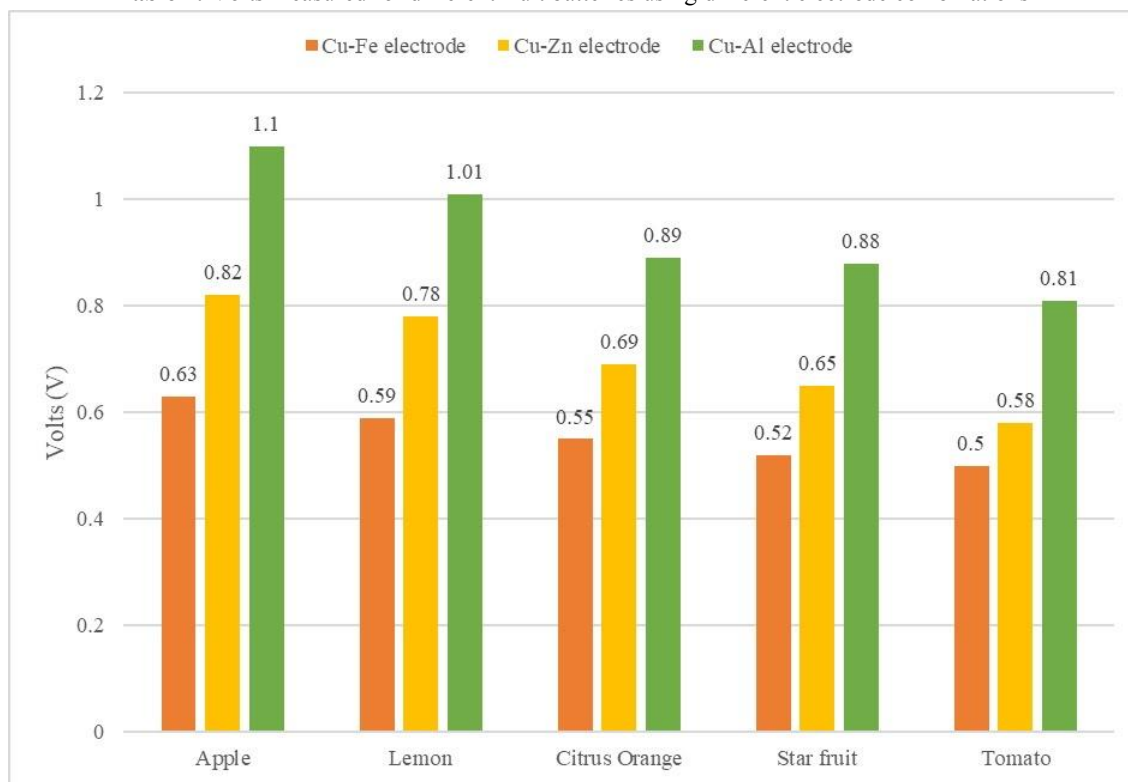


Figure 3: Voltage Characteristics for electrode combinations from different fruits

V. CONCLUSION AND SUMMARY

From the present investigation, it is clear that the fruit battery reactions generate voltages and the voltage produced are different for different types of fruits. For every fruit, maximum voltage is produced by Cu-Al electrode and least value by Cu-Fe electrode; the Cu-Zn electrode gives an intermediate voltage. These results are in agreement (directly proportional) with the standard cell potential values of 0.78 V, 1.10 V and 2 V for Cu-Fe, Cu-Zn and Cu-Al respectively, which in turn is based upon the relative positions of metal electrodes in the electrochemical series. Further investigations such as the effect of various factors like surface area of electrodes, other electrode combinations, temperature etc. on electricity generation from fruit batteries can optimise the system for maximum productivity. Since

the concept of electricity production from fruits and vegetables is a relatively new invention, there is wide scope for further studies.

REFERENCES

- [1]. Cindrella L, Hui-Zhen Fu, and Yuh-Shan Ho, (2014). Global thrust on fuel cells and their sustainability—an assessment of research trends by bibliometric analysis. *International Journal of Sustainable Energy*, 33(1), pp. 125-140.
- [2]. Khan, K. A., Hassan, L., Obaydullah, A. K. M., Azharul Islam, S. M., Mamun, M. A., Akter, T., Hasan, M., Alam, S., Ibrahim, M., Rahman M. M., & M. Shahjahan, (2018). Bioelectricity: a new approach to provide the electrical power from vegetative and fruits at off-grid regions. *Microsystem Technologies* volume 26, pp: 3161–3172.
- [3]. Sorey, T., Hunt V., Balandova, E., Palmquist, B (2012). *A new twist on the old lemon battery*. NSTA press. New York. Pp. 91-98.
- [4]. Synder, C.H (2004). *The extraordinary chemistry of ordinary things*. 4th ed. John Wiley and sons. Hoboken, New Jersey.