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Research Article

Construction and evaluation of electrical properties of a lemon battery

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Abstract: The objective of the research was to develop a lemon battery and determine the electrical properties of lemon battery. The main hypothesis of the research work was to determine whether lemon can produce electricity or not. Lemon has a voltaic cell which changes chemical energy into electrical energy. By a series circuit, conductor (copper) inserted into lemon to generate voltage. Three varieties of lemon such as Kagoji, Sarboti and Elachi were used for the experiments. Elachi could produce maximum 1.0±0.1 v voltage and 1.25±0.05 mA electricity. Overall, the electricity production was very low due to low amount of citric acid in the lemons. However, lemon could produce minimum electricity which might be used in the Light emitting diode (LED).

Keywords: Lemon, battery, voltage, electricity

INTRODUCTION

Citrus fruits belong to the Rutaceae family which are acidic and contain a healthy nutritional content. According to Food and Agricultural Organization (FAO), approximately 40-60% of citrus production processes for juice production of which 50-60% ends up as wastage. The global citrus waste production was 15-25 million tons a year. Citrus waste creates problem to the environment, thus a sustainable handling of citrus waste is desirable[1]. Bio electricity generation is reported from waste water using a microbial fuel cell[2-4]. Lemon, orange and grapefruit are examples of biomass and commonly known as citrus fruit[5]. They contain citric acid, sugar and other ingredients with sufficient chemical energy that can be converted into electrical energy by means of redox reaction with a specific condition and thus be utilized as batteries to light up light emitting diode (LED) and power up clock or calculator etc[6-7].

Batteries are containers that store chemical energy, which can be converted to electrical energy or what we called electricity. They depend on electro-chemical reaction to do this. The reaction typically occurs between two pieces of metal called electrodes and a liquid or paste called electrolyte. It is found that the citric acid contained in citrus fruit may act as an electrolyte, which enables the generation of electricity just the same way as a galvanic battery[8]. There are many variations of the lemon cell that use different fruits or liquids as electrolytes and metals other than zinc and copper as electrodes. A lemon battery is the simplest form of battery. Typically a piece of zinc metal and a copper piece is inserted into the lemon cell and connected by wires. Power generated by reaction of metals is used to power some devices like light emitting diode (LED), digital watch, mobile phone etc. The lemon battery is similar to the first electrical battery invented in 1800 by Alessandro Volta, who used brine (salt water) instead of lemon juice. The lemon battery illustrates the same type of chemical reaction (oxidation-reduction) that occurs in batteries. The zinc and copper are called the electrodes and the juice in the lemon is called the electrolyte.

The Fruit is made up of a mixture of chemicals that is called an electrolyte. An electrolyte allows charges to flow. An electrode is the part of a cell through which charges enter or exit. Each cell has a pair of electrodes from conducting materials. There are chemical changes between both the electrodes and the electrolytes. These changes convert the chemical energy to electrical energy. There are two kinds of cells in electricity. There are wet cells and dry cells. Wet cells are liquid cells like the cells in a car battery. A lemon also has wet cells which is a reason why it acts like a battery and is able to produce voltage. A lemon is able to convert to a wet cell when copper and zinc are put into it. Keeping these views into consideration the study was carried out to observe citrus fruit such as lemon as an alternative way to power a light bulb and was to determine the electrical properties such as current, voltage of a lemon battery.

MATERIALS AND METHODS

Electrolyte: An electrolyte is a substance that produces an electrically conducting solution when dissolves in a polar solvent. The dissolve electrolyte separates into cations and anions which disperse uniformly through the solvent. Electrically such solutions are neutral. Three (3) most common varieties of lemon such as Kagoji, Sarboti and Elachi which are available in Bangladesh were used for the experiment to serve as electrolyte due to the citric acid of its.

Pieces of zinc sheet metal (annode): In a battery the anode is the negative electrode from which electrons flow out towards the external part of the circuit. The pieces of zinc sheet metal used as the anode.

Pieces of copper sheet metal (cathode): In a battery the cathode is the positive terminal from which the current flows out of the device. This outward current is carried internally by positive ions moving from the electrolyte to the positive cathode.

Multi-Meter (Max Electricity: 99 A, Max Voltage: 999 V): A multi-meter is a digital meter that measures multiple things. It acts like a bunch of different meters put together into one meter. A multi-meter can be used for different purposes. It carries an ammeter, a voltmeter and even a thermometer. An ammeter measures the amount of electrical current that flows through a circuit. To measure current, an ammeter is connected in series with the current. This is so that the ammeter can measure all of the current. The greater the current in the circuit the higher the numbers are on the multi-meter. The multi-meter also carries a voltmeter. A voltmeter is a meter that measures the amount of voltage in a circuit. To measure the amount of voltage in a circuit, the voltmeter is connected parallel to the circuit. It is connected like this so almost no current flows through it. The more volts that the circuit produces, the higher the numbers are on the multi-meter. The multi-meter also carries a thermometer. A thermometer is a meter which measures the temperature. It measures how hot or cold something is. A thermometer measures the temperature of anything. The hotter the temperatures, the higher the numbers are on the multi-meter.

Single cell lemon battery: The preparation of single cell lemon battery was shown in the **flow diagram 1**.

Lemon cell

↓

Piece of copper (plate) was inserted into the one side of lemon

↓

Galvanized nail(zinc) was inserted into the other side of lemon

↓

Wires attached (metal) with copper plate (cathode) and zinc plate (anode)

↓

The wire connected with a multi-meter

↓

The reading were measured from the multi-meter

↓

Reading was positive, connected to an electrical device

Flow chart 1: Lemon battery construction

A sheet of copper plate, a zinc plate, lemon, wires and multi-meter was used to prepare single cell battery. The copper plate and zinc plate were rinsed with a light detergent. The lemon was rolled on a table, applying a small amount of downward pressure. The squeezing action released the juices inside the lemon

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needed for the battery to work. The acidity of the juice in a lemon makes it ideal for this sort of chemical reaction. It contains the solution of molecules necessary to carry electric current between the two metal ends of a battery. The slit was needed to be large enough to insert the copper plate about halfway into the lemon. The copper plate was fitted nicely into the slit that have already made. The zinc plate was to be pushed into the lemon about 2 cm away from the copper plate. These items served as the positive and negative ends of the battery. The metals were close to each other in order for the necessary chemical reaction to take place. Using the end clips of the multi-meter, one clip to the copper plate and the other clip to the zinc plate was attached. A small increase in voltage was shown on the multi-meter.

Multi cell lemon battery: In this case, multiple lemon battery was linked together (**Figure 1 & 2**).

Figure 1: Series connection of lemon battery

A sheet of copper plate, a zinc plate, a lemon (12 nos.), a knife, several wires and multi-meter was to be taken to make a lemon battery. Many lemons were linked together to increase the voltage but not the current. The lemon was rolled on a table, applying a small amount of downward pressure. The squeezing action released the juices inside the lemon needed for the battery to work. Copper-wrapped plate and zinc plate was to be made. A bit of wire was taken and wrapped for a few times around the copper plate and then took the other end and wrapped it around the top of the zinc plate. The copper plate and zinc plate were inserted into separate lemons. The wire was wrapped tightly around each piece. The battery began with a single copper-wrapped plate and end with a single copper-wrapped zinc plate. A piece of wire was to be taken and wrapped it a few times. The wire was wrapped tightly around each piece to make good connections. The slit was large enough to insert the copper plate about half way into the lemon. The copper plate needs to stay firmly in place so make sure the slit isn't too large. Twelve (12) lemons were lined up and choose one to be the first and one to be the last.

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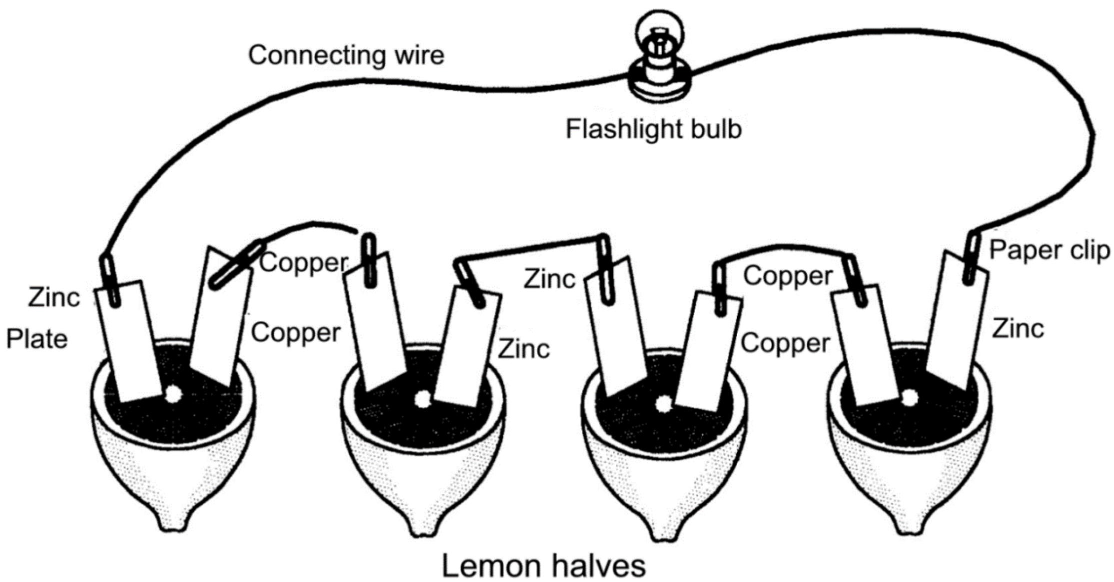

Figure 2: Circuit diagram of lemon battery

The copper-wrapped plate was stuck into the slit that could be cut into the top of the first lemon in the chain. The copper-wrapped zinc plate was inserted into the last lemon in the chain. Each lemon ultimately had one copper plate and one zinc plate stuck out of it. The first lemon in the chain already had a copper plate, the zinc plate was stuck the end of a pair into the first lemon. The second lemon was getting the copper plate from that pair. The second lemon was also getting the nail from the second pair of copper-wrapped plate and zinc plate. Using the end clips of the multi-meter, one clip to the copper wire was attached to the zinc plate and the other clip to the copper wire attached to the copper plate. An increase in the voltage reading was shown on the multi-meter.

RESULTS AND DISCUSSION

Generally, lemon juice contains 5–8% citric acid (Daniel and Charlotte, 1998) and it was the major species undergoing reaction. Overall, the lemon probably produced the most voltage because it has a higher acidity than other citrus fruits. The more the acid in a fruit, the more voltage it produces. Citric acid in a fruit acts like the acid in a battery so the fruit could produce voltage. Three varieties of lemon named Kagoji, Sarbati and Elachi were taken for the experiment. Electrical properties such as-voltage and electricity were measured. The citric acid content of the three varieties of lemon was shown in **Figure 3**.

Effect of lemon varieties on voltage production: Three different varieties of lemon such as Kagoji, Sarbati and Elachi produced minimum amount of voltage which was not sufficient to run any device (**Figure 4**). However, the average size of a lemon was 37±0.5 g, 89±1.0 g and 130±1.5 g, respectively. The verification in voltage production might be due to the variation in the citric acid. The voltage production depended markedly on the electrode materials.

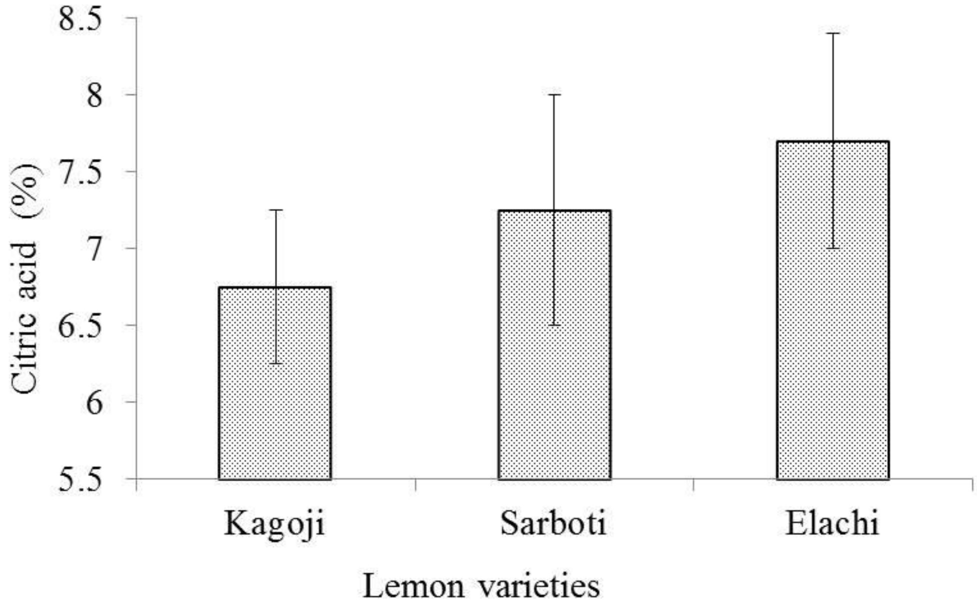

Figure 3: Effect of lemon varieties on the citric acid content of lemon. Bars represent standard deviation

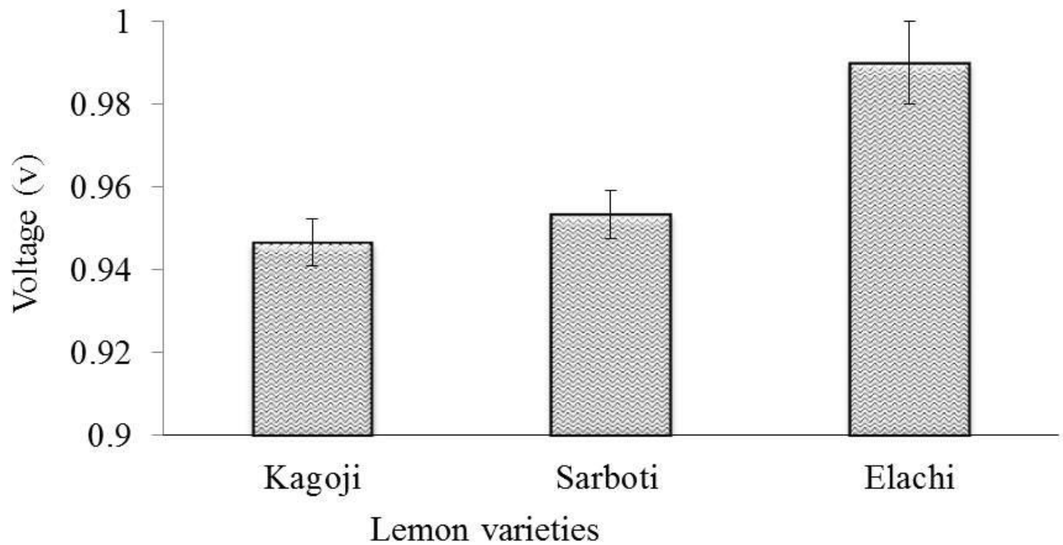

Figure 4: Effect of lemon varieties on voltage production. Bars represent standard deviation

Effect of lemon varieties on electricity production: One (1) Piece of Kagoji, Sarbati and Elachi produced 1.15±0.05 mA, 1.20±0.1 mA and 1.25±0.05 mA, respectively (**Figure 5**). There was no significant difference among three varieties of lemon though Elachi produced the highest amount of electricity. However, the electricity produced by all of the varieties was not enough to run high power devices.

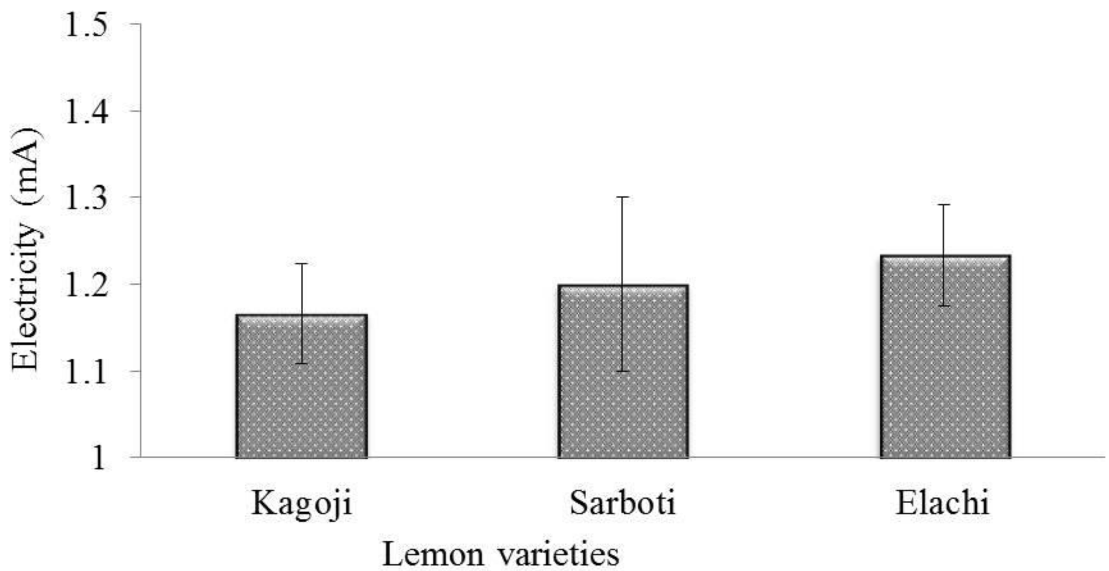

Figure 5: Effect of lemon varieties on electricity production. Bars represent standard deviation

Relationship between lemon varieties and voltage production in a series connection: To observe the more significant effect of lemons on voltage and electricity production, lemons were connected in series to power LED (**Figure 6**).

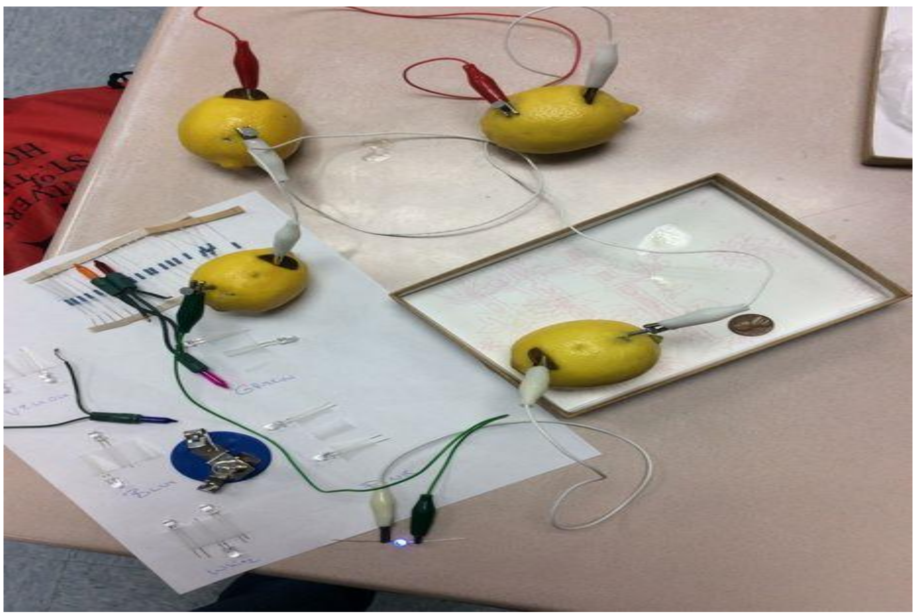

Figure 6: Series connection of lemon batteries with LED

The series connection increased the voltage available to devices. Twelve (12) lemons in series connection could be power to a white LED light. The voltage produced from the series connection was 11.9±0.05 v **(Figure 7**). It was noted that this lemon battery could create enough electrical current to run an LED. Connecting a series of lemons could produce more voltage to run small devices.

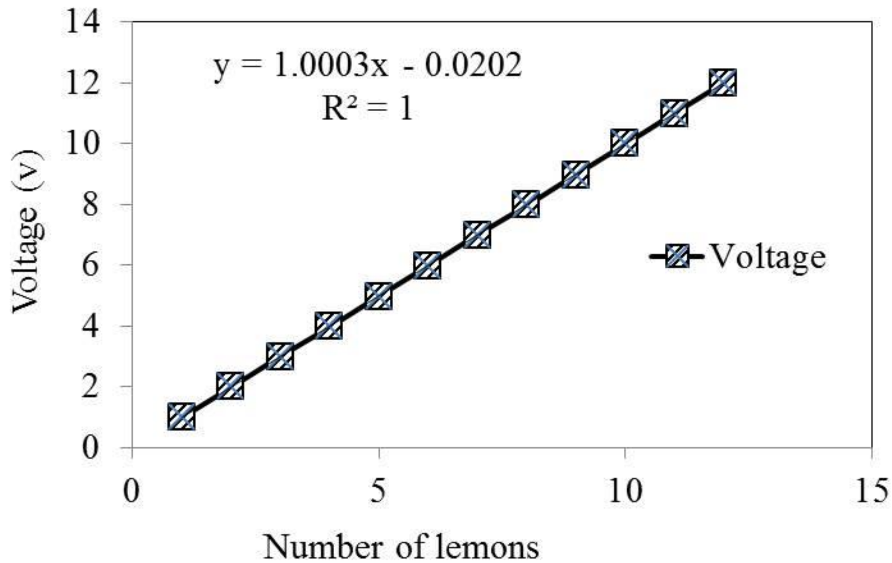

Figure 7: Relationship between lemon numbers and voltage production. Bars represent standard deviation

Mechanism and working principal reaction: The cell is providing an electric current through an external circuit, the metallic zinc on the surface of the zinc electrode is dissolved into the solution. Zinc atoms dissolve into the liquid electrolyte as electrically charged ions (Zn^{2+}), leaving 2 negatively charged electrons (e^-) behind in the metal:

$$Zn \rightarrow Zn^{2+} + 2e^- \qquad [1]$$

This reaction is called oxidation. While zinc is entering the electrolyte, two positively charged hydrogen ions (H^+) from the electrolyte combine with two electrons at the copper electrode's surface and form an uncharged hydrogen molecule (H_2):

$$2H^+ + 2e^- \rightarrow H_2 \qquad [2]$$

This reaction is called reduction. The electrons used for the copper to form the molecules of hydrogen are transferred by an external wire connected to the zinc. The hydrogen molecules formed on the surface of the copper by the reduction reaction ultimately bubble away as hydrogen gas.

Figure 8 showed the probable atomic model for the chemical reactions. Zinc atoms enter the electrolyte as ions missing two electrons (Zn^{2+}). Two negatively charged electrons from the dissolved zinc atom are left in the zinc metal. Two of the dissolved protons (H^+) in the acidic electrolyte combine with each other and two electrons to form molecular hydrogen H_2, which bubbles off of the copper electrode. The electrons lost from the copper are made up by moving two electrons from the zinc through the external wire.

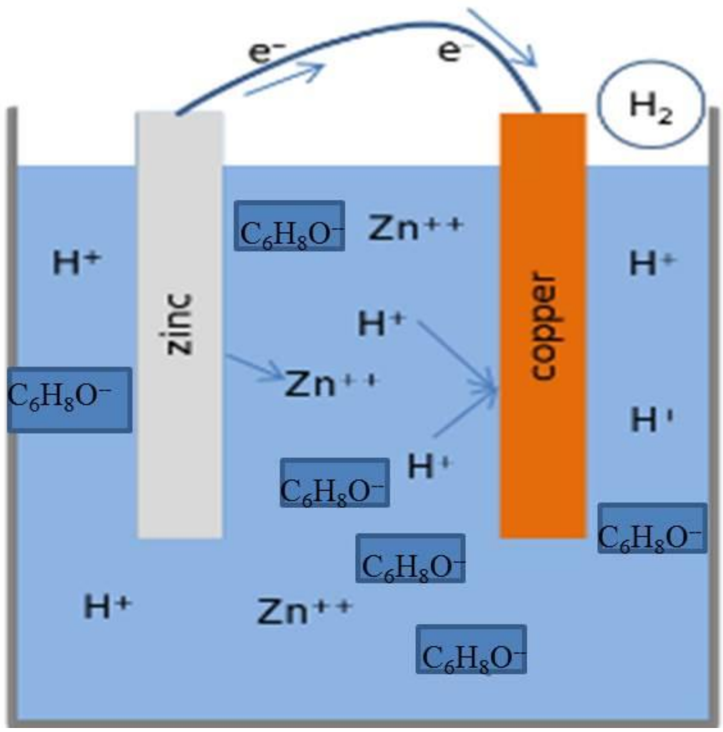

Figure 8: Probable atomic model for chemical reaction in lemon cell for the construction of a lemon battery

CONCLUSION

There was a chemical reaction between the steel in the zinc plate and the lemon juice. There was also a chemical reaction between the copper plate and the lemon juice. These two chemical reactions pushed electrons through the wire. The amount of voltage produced by one (1) lemon was not strong enough to power up devices. At least four (4) lemons were needed to power an LED bulb. Using twelve (12) lemons in series connection were enough to power a white LED light. This result will be important to people when their power goes out and they can use some lemons to power a light bulb for light. By multiplying the average electricity of a lemon (1 mA) by the average (lowest) voltage (potential difference) of a lemon (0.7 V) it can be concluded that it would take more than 100 lemons to run a mobile phone.

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