

ELECTRICITY PRODUCED FROM CITRUS FRUITS AND LOCAL FRUITS USING KIRCHHOFF'S SECOND LAW

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Abstract

The idea of using fruits as a battery has been discovered in the past. The reading of voltage and the current from the fruits were proven by using a multimeter. However, the value of the electrical current was computed in a mathematical way which was produced from the fruits. The purpose of this project is to determine which citrus and local fruits would produce the most electricity flow. The citrus and local fruits should contain high acidity content to conduct electricity and capable to be one of the power sources. This process can be applied to determine the number of citrus and local fruits required to power up a small application without conducting the real experiment. The estimated outcome of this experiment is the identification of the citrus and local fruits which could produce the highest electrical current. Perhaps using an Eco-friendly power source as a battery current might be convenient. The value of the electrical current was predicted by using a second differential equation in Kirchhoff's Second Law method as from the accomplished result. The experiment was set up by the RLC series circuit which consists of an inductor, resistor, capacitor, and the citrus and local fruits as power sources.

Keyword: Citrus fruits, Electrical current, Kirchhoff's second law, Local fruits, RLC series circuit

Introduction

Electricity is a conversion from chemical energy into electrical energy which is stored in the batteries. They would involve an electrochemical reaction to produce electricity (Buddies, 2015). The reaction occurs between two pieces of metal which are called electrodes and liquid or pastes which are called an electrolyte generally in which the electrodes require two different types of materials for a battery to work well (Buddies, 2015). This ensures that one will react contrarily than the other with the electrolyte. This difference is to generate electricity. Other than that, there is conductor that creates a connection between two electrodes with a material to transport electricity. The battery is generating electricity after the chemical reactions have been initiated (Buddies, 2015).

There are many types of electrical conductors which include a traditional electrical conductor, such as the copper and silver wires that are used to run the electrical current in homes and buildings, and ionic conductors, which can power up electricity through free moving ions. Ionic conductors that create an ionic circuit consist of organic material, such as human tissue or the potato in a typical science experiment. Ions will do all the works when it is dissolved in water which is created by electrolytes chemical compounds. Besides, according to Fantozzi (2018), electricity is conducted by fruits and vegetables the same way salt solution will complete an electrical circuit.

According to Abdullah (2018), in 1791, electrical activity was found in the nerves of the frogs that were cut apart by Luigi Galvani. Then, he assumed that electricity could only be found from animal origin and living tissues. In 1800, Volta found that organic means would produce electricity. He has created the first apparatus that was capable of producing electricity by using a small sheet of copper, zinc and cloth spacers soaked in acid solution (Gollner & Adam, 2010). Zinc and copper electrode are easily available and also sensibly safe (Abdullah, 2018). The different voltages produced by the copper or zinc and other metals like lead, iron, and magnesium can also be seen (Abdullah, 2018).

According to Wani (2018), electrolytes are from acids dissolved in water because it has good electricity conductors when it is connected to a circuit. Electricity would not conduct in any waterless form which are dry or powdered or crystalline form even it has the same acidity level (Wani, 2018). To conclude, acid is the producer of electrons while water is the conductor.

In the view of Deziel (2018), it was reported that citrus fruits contain a lot of juice which is in liquid form; with a few oranges or lemons and a few strips of zinc and copper proved that the juice is acidic. A lemon could generate electricity where it produces juice that contains electrolytes which could supply electricity. It allows two different metals to react with each other since it could not produce electricity by itself. Besides, local fruits that have high acidic content can also produce electricity by using this method and not only from citrus fruits.

The value of the electrical current can be predicted by Kirchoff's Second Law. In this project, the second-order differential equation has been used to find the value of the electrical current. Then, the solutions on how to solve the differential equation evolving from the RLC series circuit that consists of a resistor, a capacitor, an inductor and also a voltage source were identified.

It represents the law as $L \frac{d^2 Q}{dt^2} + R \frac{dQ}{dt} + \frac{1}{C} Q = E(t)$. The Electric Power formula, $P = IV$ has been applied to compute the power consumption obtained from the three types of local fruits towards its voltage and current reading.

Literature Review

The basic property of matter passed by some particles defines an electric charge. Electric charge can be either positive or negative and it occurs in discrete natural units; neither created nor destroyed.

Batteries known as galvanic electrochemical cells are products of a chemical reaction which is the store and supply of electrical energy. Batteries contain two electrodes where the first one is called an anode that generates electrons by under an oxidation process occurring at that electrode while the second one is a cathode that receives electrons by under a reduction process occurring at that electrode (Lee et al., 2004).

Redox reactions are the reaction that occurs in batteries to transfer the electrons between these two electrodes and that a pair of reactions is called a redox couple. The half-cell is a device consisting of a single electrode. A simple battery will be created when two half cells are placed in an ionic communication and the voltage potential appears between the electrodes of several sets of half cells. The redox couples chose the potential energy of the electron to produce the reaction yields electrons of sufficient potential energy to supply electrons to the electron consuming reaction (Lee et al., 2004).

To indicate low resistance to ion movement over and inside the structure, the ion batteries are exploiting the materials in their construction. Therefore, by decreasing the resistance of ions to overcome the interfaces of various phases in the battery and progress the energy storage capacity by operating materials that do not differentiate, ion batteries advance the productivity of storing and transferring electrical energy (Lee et al., 2004).

There are two types of classification of batteries which are primary batteries and secondary batteries. In primary batteries, the reagents participating in the reactions are by and largely consumed where the battery is non-rechargeable by electrochemical means. The anodic process or cathode process or both are irretrievably defined for the electrochemical process. In secondary batteries, the battery is rechargeable, because the electron produced and consume reactions are for the part reversible (Lee et al., 2004).

However, one of the renewable sources of energy that can produce electricity is lightning. According to Dongre et al. (2017), lightning is an electrical discharge between the electrically charge region within a cloud or between cloud and earth or between clouds. With some reaching more than 100,000 degrees contain in a lightning bolt, 15 million volts of electricity and rapidly heats the air around it over 60,000 degrees. Besides, the total energy of a strong thunderstorm can surpass the energy released during an atomic explosion. Also, lightning is sporadic where the energy would have to be collected and stored, but it is tough to adapt from high-voltage electrical power to the lower-voltage power that can be stored.

Moreover, there is another foremost challenge when attempting to harvest energy from lightning that is the impossibility of guessing when and where thunderstorms will happen. It is also tough to know where lightning will strike even though during a storm. Direct harvesting of atmospheric charge before it turns to lightning is one of the simple methods to solve the problem. This method was done a few times with the most acknowledged example by Benjamin Franklin's experiment with his kite (Malavika & Vishal, 2013).

According to Golberg et al. (2009), electrolysis in living tissues has already been reported by Galvani in the 18th century. Modern developments in bioengineering, micro-robotics, implantable devices and microsensors have shown significant interest in self-powered sources of electricity from implanted electrolytic batteries. Based on basic galvanic cell principles, the ability of the tissue to cause an electrical current through electrolysis was categorized. The Galvanic Apparent Internal Impedance (GAI), the fundamental and measurable tissue-specific property were revealed by reviewing Zn/Cu electrolysis in animal organs. Based on the biological samples, Male Sprague Dawley rats' internal organs were used. The result showed that the heart, lung and liver produce voltage and current.

Apart from that, copper wire and a zinc nail were both poked into three local fruits and each of the three fruits was connected to a multimeter that measured the voltage. According to Murphy and Academy (2014), the fruit that contains extra acid produced higher current voltage than the fruit that was less acidic. Voltage is the potential energy that creates the electric current flow. There will be more voltage produced if the amount of the current in the circuit is high (Murphy & Academy, 2014). The experiment was conducted by using four citrus fruits which are grapefruit, lemon, orange, lime and three local fruits which are *Mangifera indica*, *Cynometra cauliflora* and *Averrhoa bilimbi*. Copper and zinc are the negative terminals while the fruits are the positive terminal in the battery. The fruits were selected due to the fact that the fruits contain an acidic quality and it can produce voltage. The fruit is made up of a mixture of chemicals that is called electrolyte. An electrolyte allows charges to flow.

A digital meter that has been used is a multimeter that will measure several components. It carries an ammeter, a voltmeter and even a thermometer then acts as a group of different meters that put together in one meter (Jakia et al., 2018). The amount of electrical current flows through a circuit is measured by an ammeter (Jakia et al., 2018). The voltage is measured by using a multimeter that connected to zinc nail and copper wire (Murphy & Academy, 2014). This method was then continued with the *Mangifera indica*, *Cynometra cauliflora* and *Averrhoa bilimbi*. The squeezing action to release the juices inside the local fruits is conducted. The acidity of the juice in the three types of local fruits makes it ideal for

this sort of chemical reaction. It contains the solution of molecules between the two metals at the ends of a battery which will carry the electrical current.

The lifespan of fruits battery that could be used to a device was being examined. According to Dunford (2010), the charge and current equations can be determined by using Kirchhoff's Voltage Law. This will help to predict the period of fruit battery by using mathematical modeling. There are many types of different battery models that were developed by researchers over the years. However, only one model will compute the lifespan for specific discharge profiles generally.

Gustav Robert Kirchhoff, who is the first German physicist had his research "Laws of Closed Electric Circuits" published in 1845. He was a student studying under the direction of F.E. Neumann. Then he formed Kirchhoff's laws and it has been used in the electrical engineering field. It allowed the computations in an electrical circuit which involve multiple loops in currents, voltages and resistances. There are two well-known Kirchhoff laws which are Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL). These laws are generalized by the equation initiated by Georg Simon Ohm as well as by Maxwell. The system of equations that can be derived from these laws along with Ohm's law is the mathematical basis for the theory of resistive circuits (Maloberti & Davies, 2016). Kirchhoff's Voltage Law defined the diffusion of electrical voltage of an electrical circuit within a loop or closed conducting path. It stated that the algebraic sum of voltage (potential) differences in any loop must be equivalent to zero. Electrical energy in the system is signified by voltage as the conservation of energy. Any increases and decreases along the loop should being undo for a total change of zero whenever it has the same potential at the starting point. It will have two different values at either start or endpoint if the potential is other than zero point (Jones, 2019).

In this project, different available mathematical models are provided. To produce a good battery model, it's combination with a workload model has been evaluated according to the suitable models. Kirchhoff's second law has been applied to find the value of the electrical current by a calculation. The energy produced by each of the fruits will be predicted through those values in mathematical ways.

Materials and Methods

Eco-friendly power source is the best model to produce electricity by using four citrus fruits which are grapefruit, lemon, orange, lime and three local fruits which are *Mangifera indica*, *Cynometra cauliflora* and *Averrhoa bilimbi* in a liquid form of 30 milliliter (ml) in volume. In this project, the second differential equation in Kirchhoff's Second Law method has been used to find out the value of the electrical current from the citrus and local fruits.

Experimental Setup

By using the primary data, the voltaic cell experiment was chosen. A voltaic cell produces electrical energy from chemical energy. All the data has been recorded. **Figure 1** shows an experiment of voltaic cells.

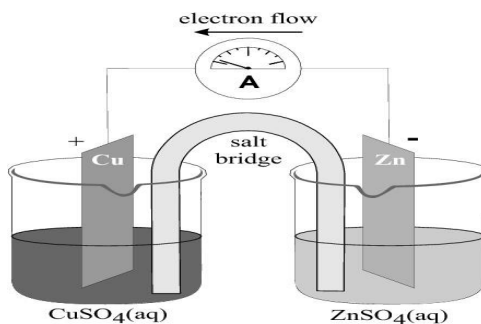


Figure 1 Experiment of voltaic cells

Four types of citrus fruits and three types of local fruits in the form of liquid with the same level of volume of 30ml were used to lead this experiment (**Figure 2**).



Figure 2 30ml of citrus fruits and local fruits juice

Equation

Kirchhoff’s second law is used to solve the differential equation arising from the RLC circuit that consist of a resistor, a capacitor, an inductor and a voltage source as shown in **Figure 3**.

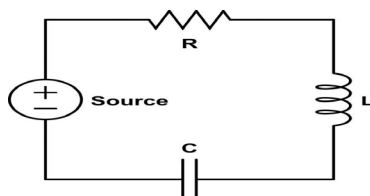


Figure 3 RLC circuit

The resistor is a circuit element satisfying Ohm’s Law. The capacitor is a device that stores electrical energy while an inductor is storing magnetic energy. According to Judson (2019), the impressed voltage, $E(t)$, is measured in volts, the resistance R is measured in ohms, and the capacitance C is measured in farads. The charge on the capacitor $Q(t)$ at time t is measured in coulombs. Inductance on the coil, L , is measured in henrys. The potential drops across each circuit element are given by:

- The voltage drop across a capacitor = $\frac{Q}{C}$
- The voltage drop across a resistor = IR (Ohm’s Law)
- The voltage drop across an inductor = $L \frac{dl}{dt}$

The sum of the drops in electrical potential is set equal to the rises in electrical potential.

$$V_L + V_R + V_C = V_S \tag{1}$$

Adding these potential drops, we set them equal to the voltage supplied by the voltage

sources which is citrus fruits. Thus, we obtain ;

$$L \frac{dl}{dt} + RI + \frac{1}{c} Q = E(t) \quad (2)$$

Since, current (I) and charge (Q) are related by,

$$I = \frac{dQ}{dt} \quad (3)$$

Hence, the formula obtained a non-homogeneous equation,

$$L \frac{d^2Q}{dt^2} + R \frac{dQ}{dt} + \frac{1}{c} Q = E(t) \quad (4)$$

In this case, the solutions corresponding to each root are linear independent. Therefore, the general solution is

$$Q_c(t) = C_1 e^{\lambda_1 t} + C_2 e^{\lambda_2 t} \quad (5)$$

For the particular solution of (2), Q_p of the non-homogeneous equation, we are using the method of undetermined coefficients. Hence, the general solution of the non-homogeneous equation is

$$Q(t) = Q_c(t) + Q_p(t) \quad (6)$$

The Reading of Voltage and Current

In this voltaic cell, zinc and copper plates were used as electrodes. The chemical reactions that take place inside the cell caused the flow of electrons. Hence, electricity is produced. They were put into the grapefruit juice and then connected to the multimeter. The multimeter measured the voltage and current of the grapefruit juice. This method was continued with the orange juice, lemon juice, lime juice, *Mangifera indica*, *Cynometra cauliflora* and *Averrhoa bilimbi*. The following **Figure 4** shows the reading of fruit voltage.

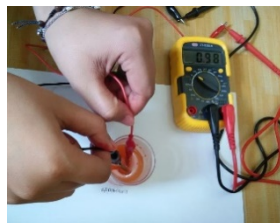


Figure 4 Voltage of citrus fruits and local fruits juice

Then the same method was used to get the reading of electrical current. The **Figure 5** is shown below.

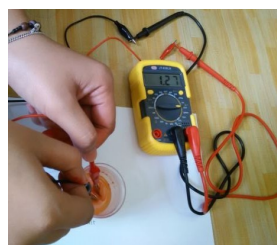


Figure 5 Current of citrus fruits and local fruits juice

Implementation of Kirchhoff's Second Law on RLC Series Circuit

In this section, second order differential equation by Kirchhoff's Second Law was applied

through an experiment to get the value of current electricity. To make the RLC series circuit, a resistor, a capacitor and an inductor are used. The suitable value of resistance, capacitance and inductance are considered. An RLC series circuit was set up which is containing the value of resistance, 3.3×10^4 ohms, capacitance, 4.7×10^{-4} Farad (16V) and inductance with 1×10^{-5} Henry (0.5 Watt). The reading of voltage and current was recorded by set up the circuit as shown in **Figure 6**.

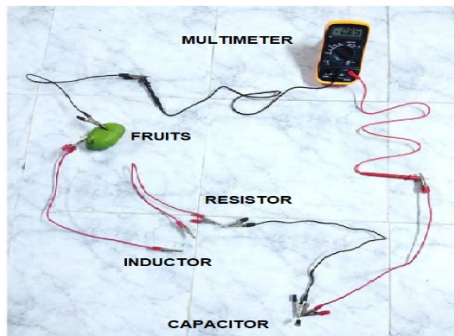


Figure 6 RLC series circuit

From equation (4),

$$Q'' + (3.3 \times 10^9)Q' + (2.1277 \times 10^8)Q = -85000$$

By auxiliary equation, $r_1 = 0$ and $r_2 = -3.3 \times 10^9$

From $q_n(t) = c_1 e^{r_1 t} + c_2 e^{r_2 t}$, $q_p(t) = -85000$, $q'_n(t) = 0$, $q''_n(t) = 0$ and equation (4) become

$$(2.1277 \times 10^8)A_0 = -85000$$

and it is obtained $A_0 = -3.9949 \times 10^{-4}$

Therefore, general solution $q(t) = c_1 + c_2 e^{(-3.3 \times 10^9)t} - 3.9949 \times 10^{-4}$

Then assuming $i(0) = 0, q(0) = 0, q'(0) = 0$,

$$q'(t) = c_1 + (-3.3 \times 10^9)c_2 e^{(-3.3 \times 10^9)t}$$

then solve c_1 and c_2 simultaneously. It is obtained $c_1 = 1.2106 \times 10^{-13}$ and $c_2 = 3.9950 \times 10^{-4}$.

Therefore $q'(0) = 2.0 \times 10^{-9}$

Hence, the value of the current is given by *Mangifera Indica* is $q'(0) = 2.0 \times 10^{-9}$. The same method used for Grapefruit and the current is $q'(0) = 1.1 \times 10^{-9}$.

Result and Discussion

The Reading of Voltage and Current

The result shows in **Table 1** and **2** the comparison of local fruits and citrus fruits of its voltage from the first reading until the fifth reading. The average of local fruits shows that *Mangifera indica* has the highest voltage which is 0.554 compared to *Cynometra cauliflora* and *Averrhoa bilimbi*. Thus, it shows that Grapefruit has the highest voltage which is 0.978 compared to lime, lemon and orange.

Next, the same method as above has been applied to get the reading of current from the first reading until the fifth reading. It can be concluded that *Mangifera indica* has the most value of electrical current among others which is 0.434 milliampere. Followed by *Averrhoa bilimbi* and lastly *Cynometra cauliflora* for the lowest value. Hence, it was shown that Grapefruit has the highest value which is 1.262 milliampere compared to lime, lemon and orange.

Table 1 The Reading of Voltage (Local Fruits and Citrus Fruits)

Voltage (V) Reading	Local Fruits			Citrus Fruits			
	<i>M. indica</i>	<i>C. cauliflora</i>	Av. Bil	Grapefruit	Lime	Lemon	Orange
1	0.56	0.50	0.43	0.97	0.92	0.90	0.84
2	0.58	0.51	0.44	0.98	0.89	0.88	0.85
3	0.60	0.49	0.38	0.97	0.91	0.89	0.84
4	0.55	0.46	0.39	0.99	0.90	0.91	0.84
5	0.48	0.47	0.41	0.98	0.91	0.90	0.83
Average	0.554	0.486	0.410	0.978	0.906	0.896	0.840

Table 2 The Reading of Current (Local Fruits and Citrus Fruits)

Current, I (mA) Reading	Local Fruits			Citrus Fruits			
	<i>M. indica</i>	<i>C. cauliflora</i>	Av. Bil	Grapefruit	Lime	Lemon	Orange
1	0.39	0.20	0.41	1.27	0.90	1.02	0.84
2	0.47	0.26	0.43	1.27	1.00	1.01	0.83
3	0.38	0.28	0.44	1.26	1.10	1.01	0.84
4	0.48	0.29	0.39	1.25	0.90	1.02	0.85
5	0.45	0.31	0.45	1.26	0.90	1.03	0.84
Average	0.434	0.268	0.424	1.262	0.960	1.018	0.84

The Reading of Electrical Power

Through this experiment, we are using the power formula $P=IV$ where P stands for power, I is current and V is a voltage to find out the type of fruit that recorded the most electricity. From the result of citrus fruits, grapefruit has the highest amount of electricity with 1.234 Watt and for the local fruits, *Mangifera indica* recorded the highest power with 0.240436 Watt (**Table 3**).

Table 3 The Value of Power(P) for Citrus Fruits and Local Fruits

Citrus Fruits		Local Fruits	
Type of fruits	P=IV	Type of fruits	P=IV
Grapefruit	1.234236	<i>Mangifera indica</i>	0.24036
Lime	0.86976	<i>Cynometra cauliflora</i>	0.130248
Lemon	0.912128	<i>Averrhoa bilimbi</i>	0.17384
Orange	0.7056		

The Value of Electrical Current by Kirchhoff's Second Law

Based on the experiment, the value of the electrical current in the RLC series circuit can be obtained by a calculation. *Mangifera indica* has been chosen as a power source in this circuit as it produces the highest electrical power. Hence, the value of the electrical current can be drawn without conducting the real experiment. There is no difference value of resistance, inductance and capacitance of both *Mangifera indica* and Grapefruit. But the highest voltage reading of *Mangifera indica* is -0.85 while Grapefruits 0.15. Thus, as the calculation from the equation done above, it is shown that the result of Mangifera Indica is 2.0×10^{-9} which is higher than the Grapefruit with the value of current 1.1×10^{-9} (**Table 4**).

Table 4 The Value of Electrical Power of Grapefruit

		Grapefruit	Mangifera Indica
By using Kirchhoff's Second Law	Resistance	3.3×10^4	3.3×10^4
	Inductance	10^{-5}	10^{-5}
	Capacitance	4.7×10^{-4}	4.7×10^{-4}
	Voltage	0.15	-0.85
	Current	1.1×10^{-9}	2.0×10^{-9}

Conclusion

To conclude, *Mangifera indica* was chosen as it produced the most electricity flow among the other two local fruits. From the subsection of the RLC series circuit, the value of E(t) for *Mangifera indica* is -0.85 where the calculation has been computed by using a Maple software as a proof of the value stated as shown in an auxiliary equation. The best result of electrical current by a calculation for local fruit is 2.0×10^{-9} Ampere while citrus fruit is 1.1×10^{-9} Ampere. Perhaps there is an error that occurred in determining for the assumption of initial value from the multimeter. To obtain the best result there must be an accuracy of both voltage and current reading. Lastly, as for the recommendation, the equipment have to be more sensitive that could replace a multimeter to obtain accurate voltage and current reading.

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Conflict of interests

Authors hereby declare that there is no conflict of interest with any organization or financial body for supporting this research.

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