Effect of Altitude droplet on over-voltage energy harvesting

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ABSTRACT

Energy harvesting is the harvesting of power by utilizing the droplet flow that passes through the taro leaves' surface, thus creating electron jumping. This study used an actual experiment. The research was carried out by varying the droplets' height on the taro leaves the surface. The variation in droplet heights uses 5 cm, 10 cm, and 15 cm. When the water droplets touch the taro leaf covered with aluminum foil as an electrode, it causes an electron to jump underneath. This phenomenon occurs within the realm of experiments or electrochemical processes, where the taro leaf acts as a conductor connecting a power source to a solution or substance undergoing reaction. This electron jump will be read by a digital multimeter connected to a laptop as a voltage. The results showed that the higher the droplets on the surface of the taro leaves, the greater the electric voltage generated. The relation between altitude and the resultant voltage is that the greater the distance of the water droplets in contact with the taro leaves the higher the voltage electricity is. The tremendous voltage was when the height of the droplets onto the taro leaves is 10 cm. In comparison, the highest voltage was the first drop on the leaf surface. As for taro leaves, it is a good alternative to harvest energy during the rainy season to exchange solar technology.

Keywords: *taro leaves; drop height; voltage; surface tension*

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Introduction

Harvesting electric energy using solar technology is very efficient and advanced at this time. However, the main problem occurs during the rainy season because solar cells cannot produce energy during the rainy season. And we expect that our discoveries will help generate energy during wet seasons.

Harvesting Energy is known as energy harvesting or power harvesting. [1] conducted research, the focus was the use of a liquid flow in the form of droplets that passed through the surface of the hydrophobic polymer to the electrode on the underside to generate electrical energy using FEP as a hydrophobic polymer medium. The change in negative charge can measure the hydrophobic surface in contact with water. Many studies have been conducted to investigate this phenomenon experimentally and theoretically; namely, research showed [2] and [3].

Based on several previous studies, it is necessary to carry out further research on energy harvesting systems. The uniqueness of this research is the use of natural materials, namely taro leaves. The taro leaves have a hydrophobic surface. The surface of the taro leaves has a waxy layer, and this layer is on the top surface to protect the surface of the leaves below. This wax coating prevents the liquid from sticking to the leaf surface. This phenomenon causes taro leaves to have hydrophobic traits.

Superhydrophobic and hydrophobic surfaces have garnered substantial attention over the past two decades, primarily due to their immense potential for technical applications in developing functional surfaces that demonstrate a wide array of properties, including self-cleaning, water harvesting and more [21]. Research [4] describes the ability of the superhydrophobic traits of taro leaves to produce electrical energy. When the droplets are dropped on a particular surface, a contact angle will be formed, which greatly depends on the hydrophobicity. [5] His research could classify based on the shape of the water droplets and the contact angle. The contact angle $<30^o$ was classified as hydrophilic when the contact angle is $90^o < \theta < 120^o$ was called hydrophobic, over hydrophobic when the contact angle was $120^o < \theta < 150^o$ and super hydrophobic when contacting angle $\theta > 150^o$.

This research was conducted to find ways to harvest energy during the rainy season [13]. This study aimed to reveal the effect of droplet height on the surface of taro leaves which causes superhydrophobic traits. During the rainy season, we can expect numerous energy harvests by using taro leaves and cloud water.

Method

Traits Measurement

In this study, the taro leaves used taro leaves with superhydrophobic properties, namely Colocasia taro leaves Figure.1. Data were collected by varying the droplets' height on the taro leaves on the surface. The height variation was 5 cm, 10 cm, and 15 cm. The size was measured from the beginning of the droplet dripping to the surface of the taro leaves.

Figure 1 : Taro Leaves

This research was actual experimental research. The superhydrophobic surface was made using taro leaves with a surface area of 1x15 cm^2. An aluminum foil electrode with a surface area of 1x15 cm^2 was attached to the underside of the taro leaves. Figure 2. shows a series of all research installation units where the glass was used as a base for aluminum foil, and taro leaves were attached. Then the taro leaves and aluminum foil were connected by a wired sensor to a digital multimeter to measure the voltage. Acquisition data collection started when water droplets were dropped vertically from the top of the leaf and started to jump electrons. Electric voltage due to electron jumping occurred when water droplets came into contact with the leaf surface [18]. A digital multimeter connected to a laptop recorded the events. A camera with high speed observed the droplet traveling through a 15 cm long leaf trajectory. Various droplet distances, namely 5, 10, and 15 cm voltage data collection.

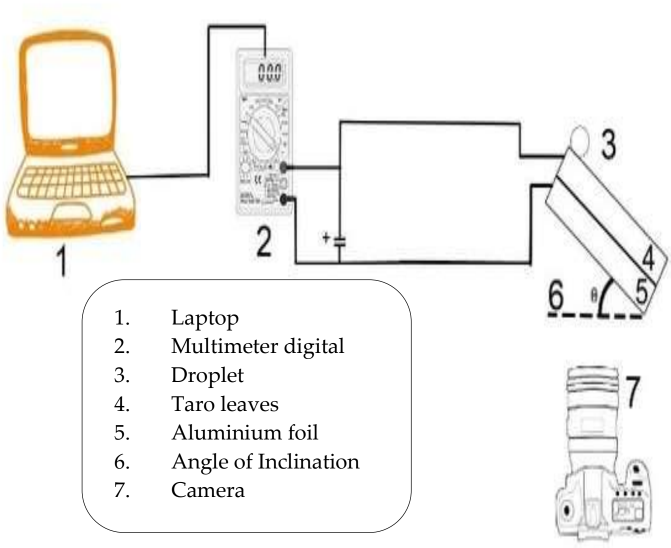


Figure 2 : Research Installation

Result and Discussion

The content of chemical elements in the leaves of taro is shown in the table below,

Table 1 : Chemical Element of Taro Leaves

Element	Percentage (%)
C	51.06
N	3.66
O	37.25
Mg	0.54
Cl	0.98
K	5.19
Ca	1.32

P	0
S	0

As shown in Table 1. the leaf surface contained several chemical elements. The most components were Carbon (C), followed by Oxygen (O). Although they include minor features, Mg, K, and Ca were reactive metal elements with good electrical conductivity.

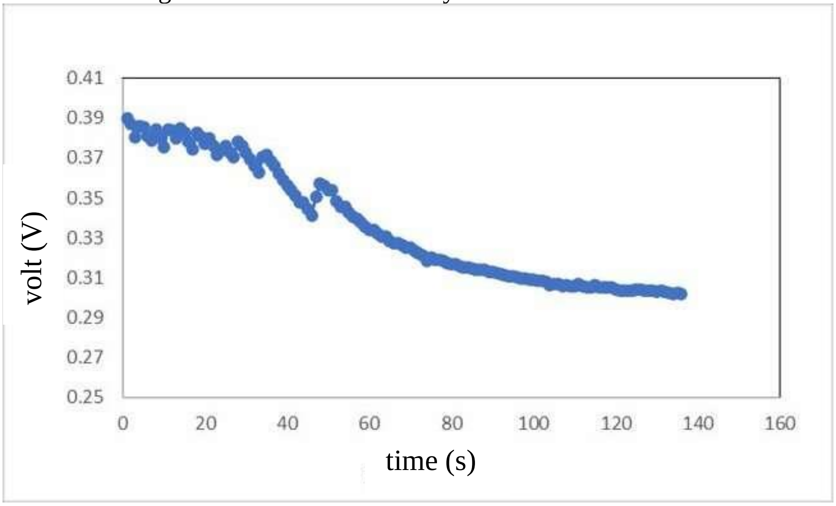


Figure 3 : Droplet Voltage-Time with a height of 5 cm

Figure 3 shows the voltage with the droplet height distance to the taro leaf surface, which was 5 cm. The first voltage of the droplets touched the surface of about 0,3964 V. During the 140 seconds. As seen at the beginning, the voltage generated by the droplet is high. When the droplet rolls, the tension drops. Touching the droplets to the surface of the taro leaves caused an electron to jump [16]. However, the electron jump was not too volatile based on the digital multimeter measuring instrument reads.

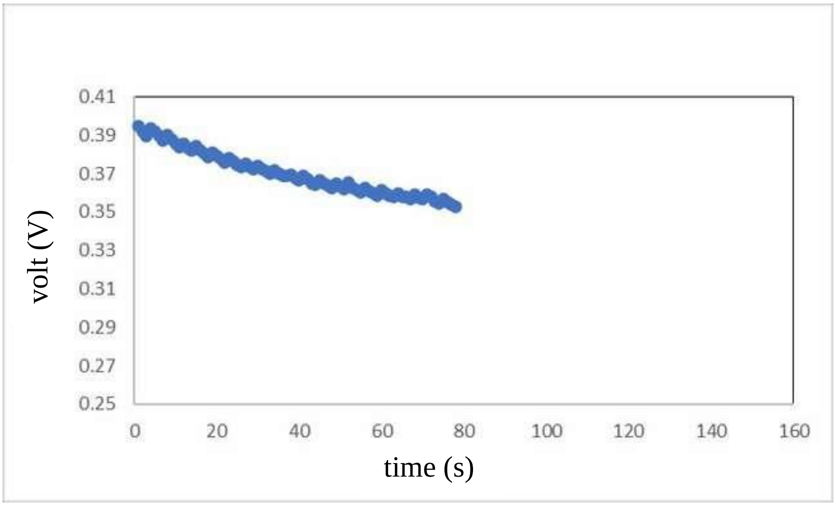


Figure 4 : Droplet Voltage-Time with a height of 10 cm

Figure 4. shows the magnitude of the voltage generated from the droplet droplets. The graph showed that the tremendous voltage was at the beginning of the droplet dripping onto the leaf surface, namely 0.40 V. Then, the voltage rises and falls until the droplets do not touch the taro leaves' surface for 80 seconds

Figure 4. shows the magnitude of the voltage generated from the droplets. In the graph, the most excellent voltage was at the beginning of the droplets dripping onto the leaf surface, namely 0.40 V. Then the voltage-time droplets rolled on the taro leaf surface, and finally, the droplets did not touch the taro leaf surface anymore. The factor that caused electron jumping was surface voltage. The jumping of electrons created an electric voltage. Figure 4 showed that the resulting voltage was higher than the leaf surface's 5 cm and 15 cm voltage. The higher the drop in the droplet caused, the higher the voltage produced. Therefore, the drop height of the droplets affected the voltage because the impact was getting stronger.

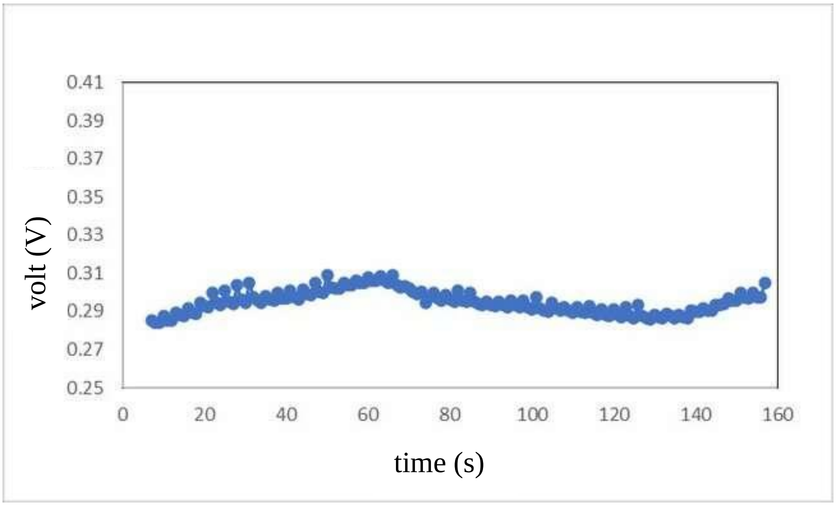


Figure 5 : Droplet Voltage-Time with a height of 15 cm

Figure 5. shows the magnitude of the voltage generated from the droplets. In the graph, the most excellent voltage was at the beginning of the droplets dripping onto the leaf surface, namely 0.28 V. Up and down voltage, because insulated water droplets rise and fall elastically on the leaf surface, causing the surface tension and electron jumps [17]. This electron jump was the voltage by a digital multimeter measuring instrument. The occurrence of electron jumping would continue as long as water droplets were on the leaf surface. After the water droplets rolled off the leaf surface, the voltage returned to its minimal point.

Then the voltage-time droplets rolled on the taro leaf surface, and finally, the droplets did not touch the taro leaf surface anymore. The factor that caused electron jumping was surface voltage. The jumping of electrons created an electric voltage.

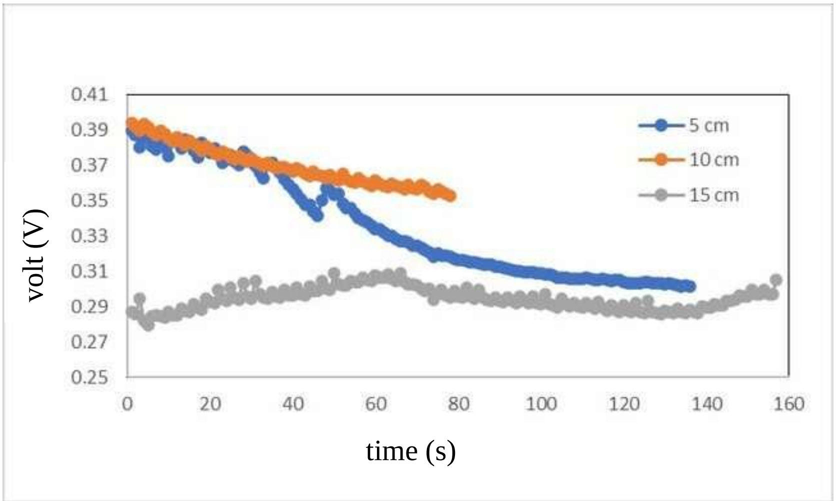


Figure 6 : Droplet Voltage-Time with height of variations

Figure 6 shows the distance of the droplets that affected the resulting voltage. The treatment of a height of 10 cm was the resulting voltage greater than 5cm and 15cm because 15 cm was the farthest distance compared to the others. When water droplets hit the leaf surface, an impulse voltage was also seen as a voltage jump. The impulse voltage increases as the height increases [6], [7]. In addition, the surface voltage that occurred between water and the superhydrophobic surface of taro leaves was identified as having the ability to produce hydrogen gas [8].

Figure 6. shows that the variation of droplet height on the harvesting of electrical energy of taro leaves affect on the voltage (v) generated [9], [12]. The blue dot on the graph shows the voltage (v) for the 5cm height variation, the orange color for the 10cm height variation, and the gray color for the 15cm height variation. The results in the experiment obtained the largest voltage (v) from variations of 5cm, 10cm, and 15cm respectively, namely 0.3964 v, 0.40 v and 0.28v.

The droplet height variation is 10cm on the graph, indicating that the resulting voltage (v) is the largest than other height variations. That's because the result of stress obtained comes from the reaction on the surface of the taro leaf when it meets water (H_2O) [14], [15]. The hydrophobic nature of the taro leaf surface contains elements of Mg, K, and Ca. The reaction that occurs when it meets the part (H_2O) is as follows:

$Mg + H20 \rightarrow Mg^{+} + OH^{-} + H^{+} + e$

$K + H20 \rightarrow K^{+} + OH^{-} + H^{+} + e$

$Ca + H20 \rightarrow Ca^{+} + OH^{-} + H^{+} + e$

This reaction creates electron jumps which are then connected to aluminum foil under the surface of the taro leaf [10]. The 10cm height variation produces the greatest stress (v) compared to the 5cm and 15cm height variations. The behavior of the droplet causes this activity; when the droplet height is lower, the possibility of the droplet experiencing reflection with a long distance and its broken or irregular shape is less and less[19]. The surface of the taro leaves in contact with the droplets is also increasing because the distance between the reflections is relatively close. This makes the reaction between the surface elements of taro leaves and water elements more and more; as a result, the resulting voltage (v) becomes even greater[20].

Droplet contact angle on taro leaves with variations in height.

The contact angle is the angle formed between the solid's surface and the liquid's surface. [11] This study's contact angle is formed between the droplet surface and the taro leaf surface, which meets when the droplet is dropped on the taro leaf.

Figures 7; 8; 9, droplet dimensions that show the dynamics of droplet droplets on the surface trajectory of taro leaves, with contact angles L for the left side and R for the right side at various height variations.

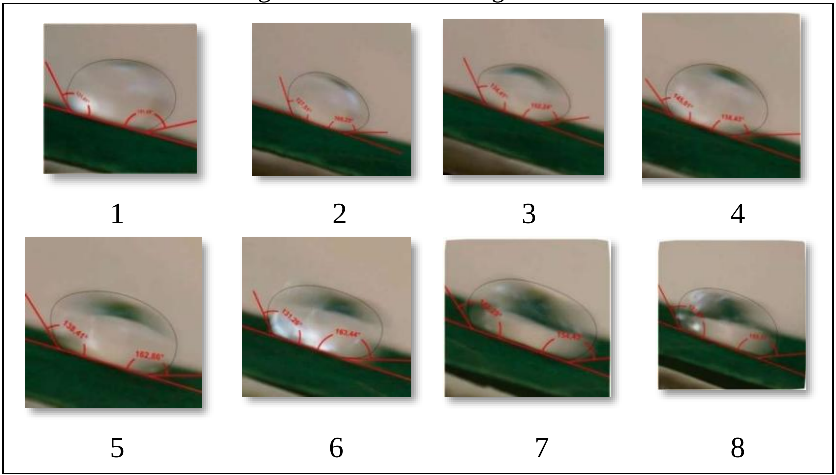


Figure 7 : Droplet dimensions at 5cm height variation

Table 2 : The value of the contact angle at a height variation of 5cm

Position	Angle	
	θ_L	θ_R
First Position(x_1= 0 cm)	131,81°	151,68°
Second Position(x_2= 0,5 cm)	127,51°	160,25°
Third Position(x_3= 1 cm)	134,41°	152,54°
Fourth Position(x_4= 2 cm)	145,01°	158,43°

Fifth Position(x_5= 3 cm)	138,41°	162,86°
Sixth Position(x_6= 4 cm)	131,26°	163,44°
Seventh Position(x_7= 5 cm)	142,29°	154,43°
Eigth Position(x_8= 6 cm)	137,00°	155,17°

Figure 7. shows the droplet at a height variation of 5cm. The initial position is when the droplet first hits the taro leaf surface (x_1=0cm). After that, positions 2 to 8 are successive trajectories of 0.5cm, 1cm, 2cm, 3cm, 4cm, 5cm, and 6cm to the initial droplet position. Changes in the shape of the unique droplet from oval to flat and vice versa, there are dimensional dynamics in the droplet. The dimensions of the droplet contact angle to the surface of the taro leaf, at a height variation of 5cm, were captured more. This variation is because at a height variation of 5cm the droplets experience a relatively smaller reflection. After all, they are closer in distance. The contact angles obtained for each dimension of the droplet with a height variation of 5cm are attached in the table.2. and the largest contact angle obtained is 163.44°.

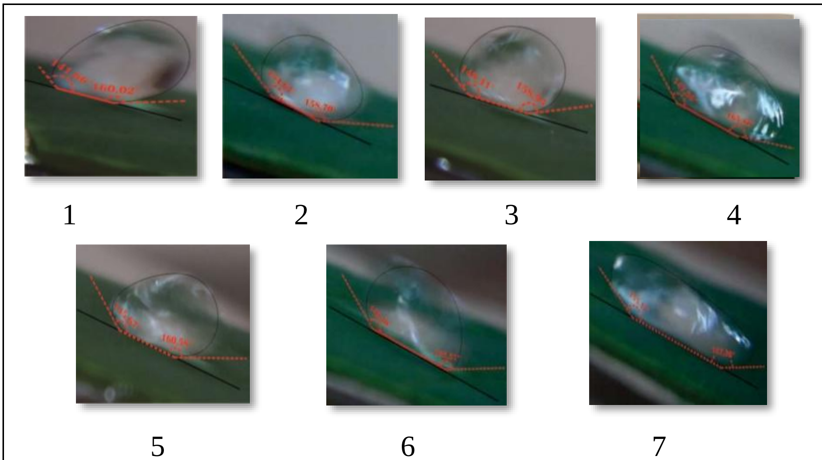


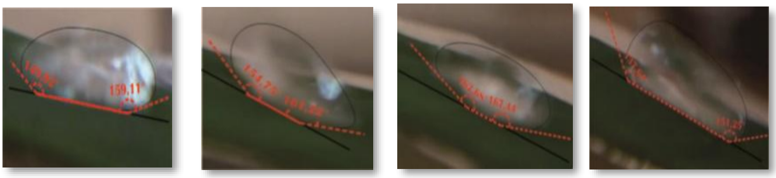
Figure 8 : Droplet dimensions at 10cm height variation

Table 3 : The value of the contact angle at a height variation of 10cm

Position	Angle	
	θ_L	θ_R
First Position(x_1= 0 cm)	141,66°	160,02°
Second Position(x_2= 1 cm)	154,67°	158,70°
Third Position(x_3= 1,5 cm)	149,41°	158,94°

Fourth Position(x_4= 2 cm)	147,59°	165,86°
Fifth Position(x_5= 3 cm)	145,67°	160,58°
Sixth Position(x_6= 4 cm)	149,70°	155,51°
Seventh Position(x_7= 4,5 cm)	155,17°	157,30°

Figure 8 droplets when flowing over the surface of the taro leaf, with a height variation of 10cm. The starting position is (x_1=0cm). After that, it is continued with positions 2 to 7, which are sequential path distances of 1cm, 1.5cm, 2cm, 3cm, 4cm, and 4.5cm. Droplet images obtained at a height variation of 10cm, are less than a 5cm height variation, which is 7 images. This cause is because at a height variation of 10cm the droplet reflects on the surface of the taro leaf, which is relatively farther away from the 5cm height variation. The contact angle obtained for each droplet with a height variation of 10cm is attached in the table. 3 and the largest contact angle is 165.58°.



1 2 3 4

Figure 9 : Droplet dimensions at 15cm height variation

Table 4 : The value of the contact angle at a height variation of 15cm

Position	Angle	
	θ_L	θ_R
First Position(x_1= 0 cm)	149,92°	159,11°
Second Position(x_2= 2,5 cm)	154,75°	161,22°
Third Position(x_3= 3 cm)	162,68°	167,44°
Fourth Position(x_4= 5 cm)	137,64°	151,65°

Figure 9 shows the droplets in contact with the taro leaves, with a height variation of 15cm. The droplet image contains 4 pictures with the initial position (X_(1=) 0cm), then positions 2 to 4, with successive trajectories of 2.5cm, 3cm, and 5cm. Droplets at a height variation of 15cm are very few droplet images that can be taken, namely 4 pictures compared to other heights. This is due to the variation in size of 15cm, the droplets reflect at a longer distance, compared to variations in height of 5cm and 10cm. The contact angle obtained for each droplet dimension is attached in table 4.4 and the largest contact angle obtained is 167.44^o.

The higher the variation in the relative height distance, the flatter the droplet shape, this indicates that there is a push from the earth's gravity (g) which causes the droplet velocity. The higher the drop, the greater the speed of the decline. This change can be seen from the change in the contact angle which is getting bigger.

The shape of the droplet looks oval to the top due to the droplet’s tendency to be elastic, due to the hydrophobic nature of the surface of the taro leaf which manages to resist, thus making the droplet oval-shaped upwards. The dimensional shape of the droplet also shows the magnitude of the surface tension, between the surface of the taro leaf and the surface of the droplet. This can be seen in the measurement of the contact angle of the image for each different variation.

Conclusion

Taro leaves from natural ingredients were effective for producing alternative energy or energy harvesting. This research revealed the emergence of electrical power from water droplets dripped with a height of 5, 10, and 15 cm when they come into contact with the surface of the taro leaves. The relationship between altitude and the resulting voltage is that the higher the distance of the water droplets in contact with the taro leaves, the higher the electrical energy in the form of voltage. This result is because the stress achieved results from the reaction on the surface of the taro when it meets the water (H2O). But this only applies at a height of 15 cm. Because at a droplet height of 15 cm, there are very few droplets that touch the taro leaves because they are too high so they roll straight away so that the impulse force that works is small.

Contributions of Authors

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

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Conflict of Interests

All authors declare that they have no conflicts of interest

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