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Fabrication of Dye Sensitized Solar Cell Using Cassava Leaf Extract and Red Dragon Fruit

T. Purnomo, A. Nayan*, M. Sayuthi, N. Islami, A. Rahman

Department of Mechanical Engineering, Faculty of Engineering, University of Malikussaleh, Jl. Batam 62-64, Lhokseumawe 24352, Indonesia
**Corresponding author email:nayan@unimal.ac.id*

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ABSTRACT

DSSC is expected to be a new technology for converting solar energy into electricity that is more environmentally friendly and affordable. This is driven by the main ingredients for making DSSC derived from nature. The purpose of this research is to identify the absorbance and consistency of the efficiency of DSSC (Dye-Sensitized Solar Cells). The study was conducted with variations of chlorophyll-anthocyanin mixture using different volumes of dye solutions: 10 ml of cassava leaf and 20 ml of red dragon fruit, 20 ml of cassava leaf and 10 ml of red dragon fruit, and 10 ml of cassava leaf and 10 ml of red dragon fruit. The Dye Sensitized Solar Cell system consists of natural dye as the colorant, electrolyte solution, two FTO glass substrates with dimensions of 2.5 cm x 2.5 cm, which function as working electrodes coated with titanium dioxide as the semiconductor using the doctor blade method, and a counter electrode coated with carbon. All components of the Dye Sensitized Solar Cell are arranged in a sandwich-like structure, with the counter electrode facing the working electrode and clamped together using paper clips. The highest absorbance value was obtained with the variation of 20 ml of red dragon fruit and 10 ml of cassava leaf compared to other mixtures. The highest efficiency and power of the Dye Sensitized Solar Cell were also obtained with 20 ml of red dragon fruit and 10 ml of cassava leaf

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Keywords: Dye Sensitized Solar Cell, Dye, Semikonduktor material, TiO_2.

1. Introduction

The world's population growth is accelerating, which means that energy demand is also increasing rapidly, with nearly 80% of that demand coming from fossil fuels (International Energy Agency-IEA). This leads to carbon dioxide emissions that can harm human life in the future. Solar energy has the potential to address society's dependence on fossil fuels. Therefore, environmentally friendly renewable technologies are needed to convert solar energy into electricity (photovoltaics). Currently, solar energy development focuses on third-generation DSSC (Dye Sensitized Solar Cell). Dye sensitized solar cell utilizes natural dyes to enhance the sensitivity of solar cells, enabling them to convert sunlight into electrical energy. The advantages of dye sensitized solar cell are its ease of production, cost-effectiveness, and environmental friendliness [1].

In addition to being abundant, solar energy is also environmentally friendly. Sunlight can be converted into electrical energy using solar cell technology[2]. The condition of Indonesia, which the equator passes through with its two seasons, also brings advantages and disadvantages. Excellence is from solar energy shines all year round and gives energy large, but average ambient temperature higher than countries that have four seasons. This of course has the potential to develop energy sources derived from the sun [3].

The sunlight is an alternative energy source that has a tremendous potential as a large energy resource to prevent energy crises. Therefore, this research is conducted to create a DSSC (Dye-Sensitized Solar Cell) to convert solar energy into electrical energy. By using solar cell technology or solar energy, light or sunlight can be transformed into electrical energy. Dye sensitized solar cell is a device that can convert solar energy into electrical energy. Researchers have developed solar cells ranging from monocrystalline solar cells to polycrystalline silicon and the latest type of solar cell, DSSC (Dye Sensitized Solar Cell). Dye sensitized solar cell was first discovered in 1991 by [1], who used dye extracts found in plants to harness sunlight and convert it into electrical energy.

Dye sensitized solar cell consists of several essential components, Namely FTO glass (Fluorine Conducting Oxide), TiO_2 (Titanium Oxide), Dye, and Electrolyte [1]. FTO glass functions as the bracket for the entire dye sensitized solar cell, with the top glass acting as the electrode, while the bottom glass serves as the reference electrode. The semiconductor material commonly used in dye sensitized solar cell is ZnO, TiO. TiO_2 is one of the most commonly used semiconductors as the main component of dye sensitized solar cell because it is readily available and relatively inexpensive. The bandgap of TiO_2 semiconductor is 3.0 eV for the rutile phase and 3.2 eV for the anatase phase. The anatase phase is more commonly used as a component in dye sensitized solar cell due to its stable structure at low temperatures. TiO_2 also plays a role in the formation of 2-holes, which act as temporary electron reservoirs for electricity [4]

DSSC electrolyte can be solid or liquid. The most common electrolyte used in the production of DSSC is the redox pair I-/I3 - (iodine/triiodide). In addition to the I-/I3 electron pair, Br2/Br-, (SCN) 2/SCN and (SeCN) 2/SeCN- can be used as electrolytes [5]

In the future, dye-sensitized solar cells are potential candidates for solar cells because they do not require highly pure materials, making the production process relatively low-cost. Unlike conventional solar cells that involve silicon materials throughout the entire process, Dye Sensitized Solar Cellseparates the processes of light absorption and electrical charge separation. Light absorption is carried out by dye molecules, while charge separation occurs within the inorganic nano-crystalline semiconductor with a wide bandgap. The use of wide bandgap semiconductors increases the number of electrons flowing from the conduction band to the valence band because the wide bandgap enhances the photocatalytic reaction space and broadens the spectrum of dye absorption [6]

2. Methodology of Research

The method used in this study is experimental research. the first step is to determine the coloring mixture to be used in the form of red dragon fruit and cassava leaves. The research begins with a literature study, namely looking for the latest references related to dye sensitized solar cellresearch, then preparing research tools and materials, followed by making a dye sensitized solar cell, after making a dye sensitized solar cell, then making a dye sensitized solar cell. research conclusions and completion. the following describes the steps.

2.1 Literature study

The initial stage involves studying the literature on previous theories and calculations in order to discuss how to conduct research on dye-sensitized solar cells using organic materials derived from plants, semiconductor materials, and other components of dye sensitized solar cell based on previous research.

2.2 Preparation tool and material

In this step, prepare the tools and materials to make dye sensitized solar cell, while the tools used are hotplates, measuring cups, analytical balances, petri dishes, spatulas, pipettes, mortar, filter paper, furnaces, Uv-Vis spectrophotometers, digital multimeters, solar power meters. , magnetic stirrer. The materials used in the manufacture of dye sensitized solar cell are cassava leaves (Manihot esculenta Crantzsin), red dragon fruit (Hylocereus polyrhizus), titanium dioxide (TiO_2), distilled water, ethanol, alcohol, acetic acid, potassium iodide (KI), iodine (I2). acetonitrile, fluorine tin oxide (FTO) glass, carbon (2B pencil).

2.3 Manufacture dye sensitized solar cell

a. *Preparation of cassava leaf and red dragon fruit extract*

Cassava leaves and red dragon fruit are finely chopped, mixed, and stirred until smooth. Then, they are weighed using a digital scale, 20 grams in total. After that, they are soaked in a container containing

25 mL of ethanol, 4 mL of acetic acid, and 20 mL of water. They are stored in a dark place for 24 hours. After 24 hours, the liquid extract is filtered through filter paper and transferred into a bottle wrapped with aluminum foil to prevent decomposition under sunlight.

Figure 1. Cassava Leaf and Red Dragon Fruit Extract

b. Preparation of FTO (Fluorine Tin Oxide) glass

The FTO glass is cut into sizes of 2.5 cm x 2.5 cm. The FTO glass plate is cleaned by soaking it in distilled water for 10 minutes. Then, it is soaked in ethanol for 10 minutes. Afterward, the FTO glass is dried.

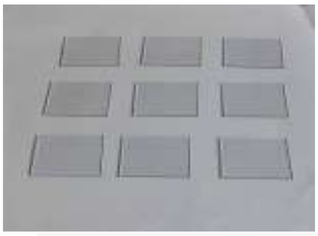

Figure 2 FTO (Fluorine Tin Oxide) Glass

c. Fabrication of TiO_2 layer on FTO using the doctor blade method

The doctor blade method is the simplest method in the fabrication of dye sensitized solar cell as it only requires a stirring rod to spread the TiO_2 layer onto the FTO glass, followed by heating (sintering) at a predetermined temperature and duration [7]. Specifically, heating serves as a binder to bond the TiO_2 atoms with the FTO glass. The temperature commonly used is below the melting point of the FTO glass.

Figure. 3 Fabrication of TiO_2 Layer on FTO using the Doctor Blade Method

d. Preparation of electrolyte

The electrolyte solution is prepared by mixing 100 grams of potassium iodide (KI) and 10 ml of acetonitrile in a glass beaker. The mixture is stirred with a magnetic stirrer for 10 minutes. Then, 0.127 grams of iodine are added, and the solution is stirred again with a magnetic stirrer for 30 minutes. Finally, the solution is stored in a closed bottle.

Figure 4. Electrolyte

e. Preparation of counter electrode layer

FTO glass and a 2B pencil are prepared for carbon deposition. The FTO glass is evenly scratched using a 2B pencil. Then, the FTO glass is uniformly heated using a candle flame.

Figure 5. Counter Electrode Layer

f. Assembly dye sensitized solar cell

Place the counter electrode (FTO glass coated with carbon) facing upward on a flat surface. Then, drop the electrolyte solution onto it using a pipette. Place the TiO_2 and dye-coated FTO glass substrate on the counter electrode. Once the layers are formed, clamp both sides of the sandwiched layers with paper clamps. The dye sensitized solar cell sandwiched layer is now ready for testing.

Figure 6 Assembly Dye Sensitized Solar Cell

3. Result and Discussion

3.1 Result of UV-Vis characterization

During characterization using UV-Vis, an absorption process occurs when photons collide directly with atoms in the material losing energy in atomic electrons. Photons will experience a slowdown and some will stop when they enter the material. The photon energy is absorbed by the atomic electron and then moves to a higher energy level. The more peaks that are formed at UV absorption and visible wavelengths, the better because the dye can absorb more photon energy which causes the electrons from the dye to move and can generate electricity. This study used a Uv-Vis spectrophotometer with a wavelength of 200-800 nm (ultraviolet to visible light). Spectrophotometer test results are displayed in graphical form the ratio of the relationship between wavelength (nm) and absorbance (%).

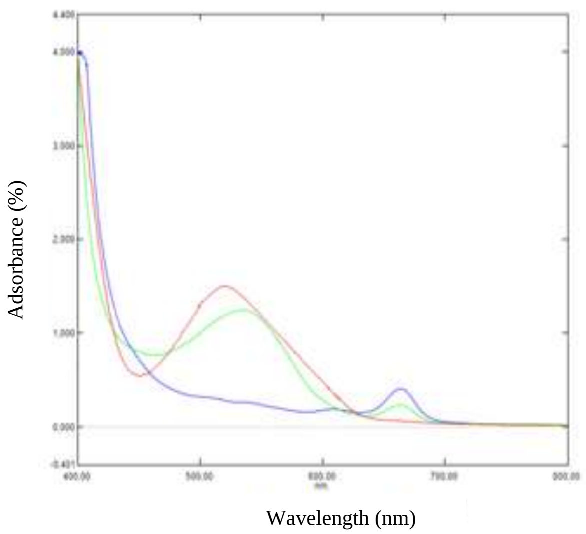

Figure 7. Absorbance Curve

Based on Figure 7 the UV-Vis spectrum of the combined dye from cassava leaves and red dragon fruit, it showed a good peak absorbance value. This shows that mixed dye research can be carried out by producing maximum efficiency in Dye Sensitized Solar Cell fabrication. For the absorption peak, the absorbance of the mixture is in the wavelength range of 500 nm-600 nm of 1.3%.

3.2 Peak sun hour

Indonesia is an archipelagic country which is illuminated by sunlight at least 10-12 hours a day[8]. However, not all sunlight can be converted into electrical energy. therefore this test was carried out using the Global Solar Atlas software, to find out the peak point of the sun which researchers will do to determine the right time to carry out current-voltage testing to get peak efficiency and power from Dye Sensitized Solar Cells. In Figure 4.5 it can be seen that the GHI (Global Horizontal Irradience) is 4.849 kWh/m2 day, which means PSH is 4.8 hours. In this case the researchers conducted a voltage current test with a period of 5 hours, namely at 10.00-15.00 on 08 February 2023 West Indonesia time at the Department of Mechanical Engineering, University of Malikussaleh Lhokseumawe Aceh with clear weather conditions.

3.3 Characterization of current (I) and voltage (V)

The test was carried out on February 8-11 at the Department of Mechanical Engineering, Malikussaleh University, Lhokseumawe, Aceh using sunlight as a light source. Current and voltage measurements were carried out according to the PSH data previously. The intensity of sunlight in the time range 11.00-15.00 is 146,566 Lux [9]. Before measuring the current and voltage, the materials are arranged in a sandwich manner, which consists of conductive glass which has been coated with dye as a light absorber and an electron transfer pen and a counter electrode which uses conductive glass which has been coated with carbon. After the Dye Sensitized Solar Cell material is formed, current and voltage measurements are carried out for 3 consecutive days which function to determine whether the current and voltage values generated by variations in dye sensitized solar cell solutions are constant, decreasing or increasing. Here are the results of current-voltage measurements for 3 days.

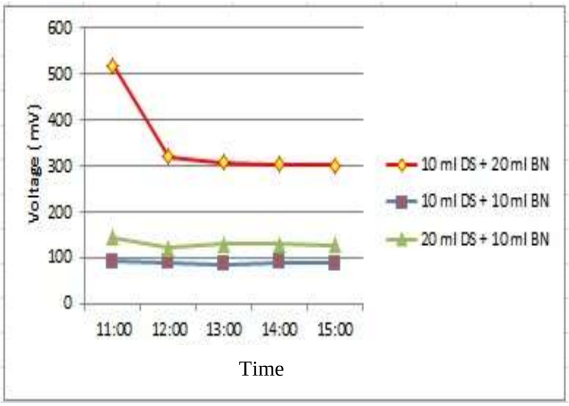

Figure 8. Voltage Measurement Results Day 1

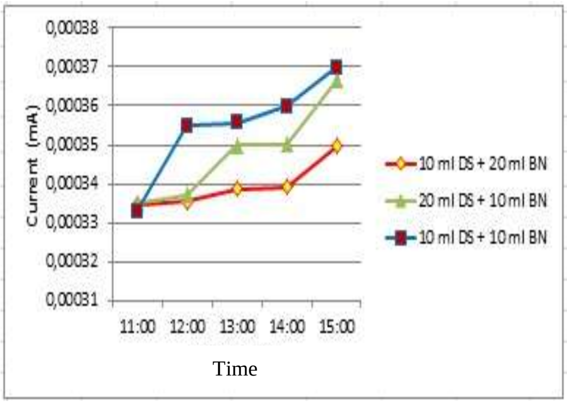

Figure 9. Current Measurements Results Day 1

Based on Figures 11 and 12 there is a change in the value of the current voltage for each variation based on testing in the peak sun hour time range. The greatest currents and voltages were generated at variations in solution volume for each combination of 10 ml of cassava leaves and 10 ml of red dragon fruit and 10 ml of cassava leaves and 20 ml of red dragon fruit at 11.00, 12.00, 13.00, 14.00 and 15.00 West Indonesian time.

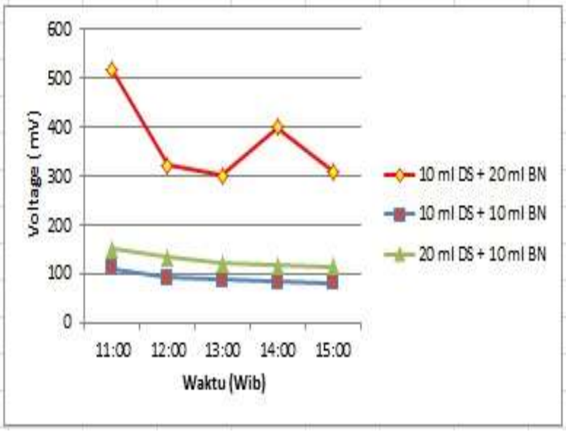

Figure 10. Voltage Measurement Results Day 2

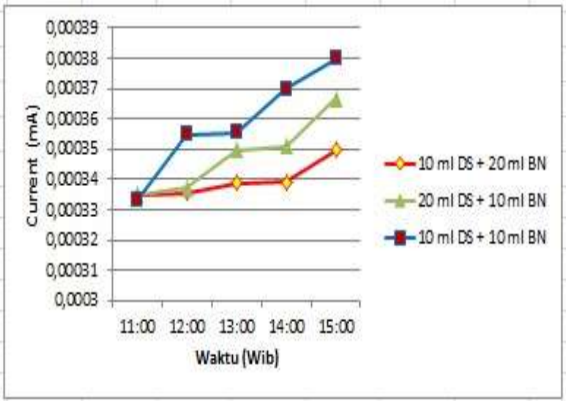

Figure 11. Current Measurements Results Day 2

Based on Figures 13 and 14there is a change in the value of the current voltage for each variation based on testing in the peak sun hour time range. The greatest currents and voltages were generated at variations in solution volume for each combination of 10 ml of cassava leaves and 10 ml of red dragon fruit and 10 ml of cassava leaves and 20 ml of red dragon fruit at 11.00, 12.00, 13.00, 14.00 and 15.00 West Indonesian time.

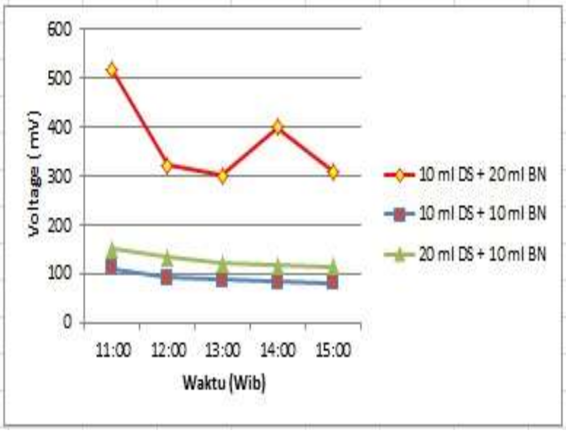

Figure 12. Voltage Measurement Results Day 3

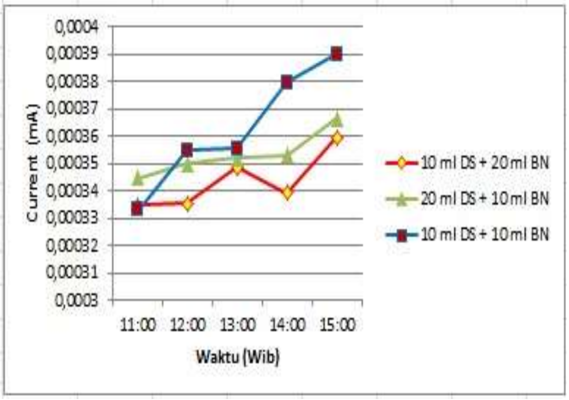

Figure 13. Current Measurements Results Day 3

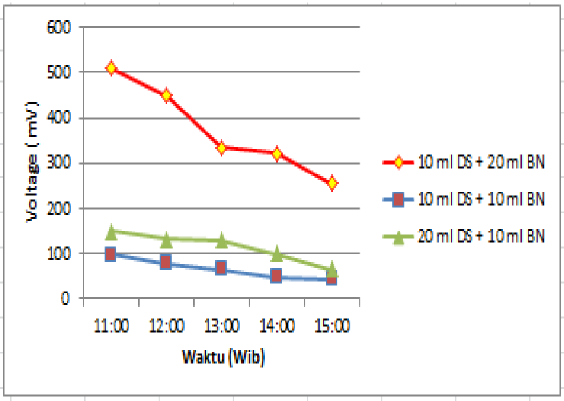

Figure 14. Measurement of the average voltage of 7 days

Based on Figures 15 and 16 there is a change in the value of the current voltage for each variation based on testing in the peak sun hour time range. The greatest currents and voltages were generated at variations in solution volume for each combination of 10 ml of cassava leaves and 10 ml of red dragon fruit and 10 ml of cassava leaves and 20 ml of red dragon fruit at 11.00, 12.00, 13.00, 14.00 and 15.00 West

Indonesian time.

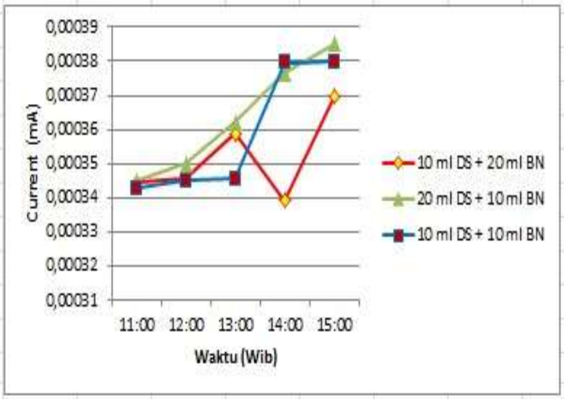

Figure 15. Measurement of the average flow of 7 days

Based on Dye Sensitized Solar Cell current-voltage measurements for 3 consecutive days, constant current-voltage values. Based on the figure above, it can be seen that the magnitude of the value of I is inversely proportional to the value of V. The higher the value of I, the smaller the value of V. Similarly, the Dye Sensitized Solar Cell voltage results show that the dye that has the highest current value is a dye mixture of 10 ml of dragon fruit and 10 ml of cassava leaves and highest voltage by a mixture of 20 ml of dragon fruit and 10 ml of cassava leaves.

3.4 *Effect of material surface temperature on dye sensitized solar cell current-voltage*

Material surface temperature measurements were carried out using a thermo gun to determine the relationship between material surface temperature and the power generated by the Dye Sensitized Solar Cell. The following is a picture of the Effect of Material Surface Temperature on Dye Sensitized Solar Cell Current-Voltage.

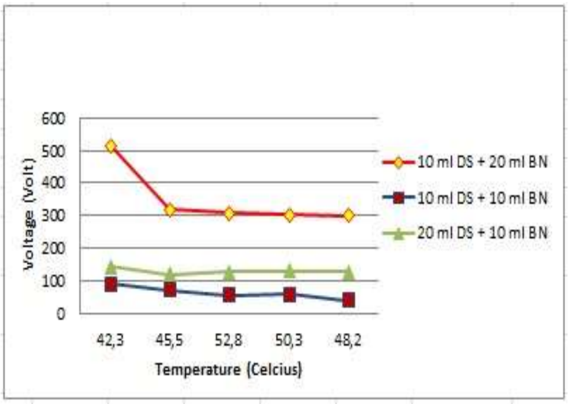

Figure 16. Effect of Material Surface Temperature on Dye Sensitized Solar Cell Voltage

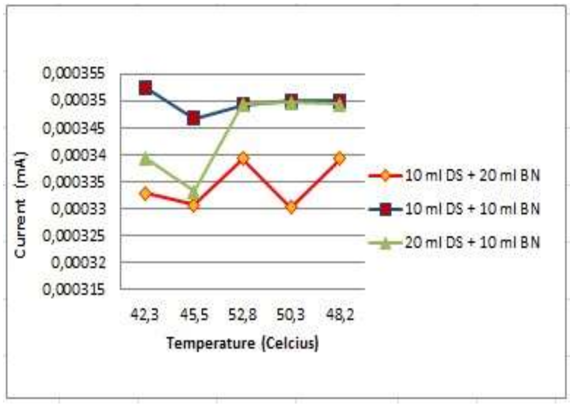

Figure 17. Effect of Material Surface Temperature on Dye Sensitized Solar Cell Voltage

It can be seen from the results of measuring the temperature of the Dye Sensitized Solar Cell material that the temperature on the surface of the Dye Sensitized Solar Cell material affects the resulting current voltage. The higher the temperature on the surface material, the power generated will also decrease and vice versa when the temperature on the surface material decreases, the resulting current-voltage increases.

3.5 *Energy yield value*

$$\overline{X} = \frac{1}{n} (\Sigma x) \quad (1)$$

Where:

$\overline{X}$ = average value
n = number of samples
Σx = amount of data

The average power generated by dye sensitized solar cell uses the equation (2)

$$P = V \times I \quad (2)$$

Where :

P = Power (watt)
V = Voltage (volt)
I = Current (ampere)

3.6 *Effeciency dye sensitized solar cell*

The average power generated for each variation of the solution, that is, a combination of 20 ml of dragon fruit and 10 ml of cassava leaves, 20 ml of cassava leaves and 10 ml of dragon fruit and 10 dragon fruit and 10 ml of cassava leaves, which are 0.0017045 , 0.000407 , 0.000022 watts.

$$\eta = \frac{P_{output}}{P_{input}} \times 100\ \%$$

Based on the formula above, the efficiency of each solution variation is produced in the table below.

Table 1. Output Power and Efficiency of Dye Sensitized Solar Cell

Solution volume	Voltage (V)	Current (A)	Output Power (W)	Efficiency (%)
20 ml BN and 10 ml DS	0,504	0,003382	0,0017045	0.004045
20 ml DS and 10 ml BN	0,121	0,0003332	0.0000407	0.001408
10 ml DS and 10 ml BN	0,07	0,0000322	0.0000022	0.0006911

According to the data table 1 above, the deficiency of a mixture of 20 ml of dragon fruit and 10 ml of cassava leaves was 0.040% better than the previous mixed Dye sensitized solar cellstudy, namely a mixture of Dragon Fruit Dye-Pandan Leaf 0.0032%, red spinach-cassava leaf dye 0, 00257 % [10] but still under research conducted by Zhan and friends at 5.63% [11].

Table 2. Output Power and Solar Cell Efficiency from Polycrystaline Silicon

Voltage (V)	Current (A)	Power Output (W)	Efeciency (%)
0,356	0,01684	0,06995	1,3%
0,359	0,01642	0,0590	1,3%
0,370	0,01102	0,00400	1,3%

The comparison table above, measurements are carried out when the sun is at its peak, which is 11.00 West Indonesian time to 15.00 West Indonesian time with clear weather. It can be seen that DSSC has an output power far below that of conventional solar cells [12], this is influenced by several factors, one of which is because it uses a liquid electrolyte that can evaporate. However, for production and maintenance costs, DSSC is very cheap and the materials are very abundant because it uses organic materials and components.

This research also proves that the first generation of solar cells has greater efficiency than DSSC, but the supporting materials for making solar cells are very expensive and come from chemicals. In addition, measurements made during cloudy weather can also cause the absorption of sunlight is not optimal, which results in a small current and voltage generated.

4 Conclusions

The effect of variations in the volume of dye mixed with red dragon fruit cassava leaves greatly affects the increase in the absorbance value. The dye with the highest absorbance value was 10 ml of cassava leaves and 20 ml of red dragon fruit, which was 1.2% at a wavelength of 512 nm compared to the other mixed dyes. The effect of using mixed dye from cassava leaves and red dragon fruit can increase DSSC efficiency and comes from mixing the highest volume of 10 ml of cassava leaves and 20 ml of red dragon fruit. The efficiency produced by DSSC is far below that of silicon solar cells, which is 0.005921% for DSSC efficiency compared to 1.3% for silicon solar cell efficiency.

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References

[1] B. O'Regan, D. T. Schwartz, S. M. Zakeeruddin, dan M. Grätzel, "Electrodeposited nanocomposite n-p heterojunctions for solid-state dye-sensitized photovoltaics," *Adv. Mater.*, vol. 12, no. 17, hal. 1263–1267, 2000.

[2] W. Hasibuan, M, "Pembuatan Protype DSSC menggunakan Kulit Ketapang," *Skripsi*, hal. 1–105, 2021.

[3] E. Syah, A. Asri, dan A. Bintoro, "ANALISA PENGARUH PERUBAHAN SUHU TERHADAP TEGANGAN PANEL SURYA JENIS MONO CHRYSTALLINE

KAPASITAS DAYA 50 Wp," *J. Energi Elektr. Unimal*, vol. 11, no. 1, hal. 22, 2022, doi: 10.29103/jee.v11i1.8260.

[4] Wang, "Synthesis and characterization of anatase TiO2 nanotubes with uniform diameter from titanium powder," *Mater. Lett.*, vol. 62, no. 12–13, hal. 1819–1822, 2008, doi: 10.1016/j.matlet.2007.10.011.

[5] Moharam, "Semiconductors as Effective Electrodes for Dye Sensitized Solar Cell Applications," *Top. Curr. Chem.*, vol. 379, no. 3, hal. 0–17, 2021, doi: 10.1007/s41061-021-00334-w.

[6] R. J. Goldfarb, "© 19 9 1 Nature Publishing Group 그라첼꺼," *Nature*, vol. 354, hal. 56–58, 1991.

[7] G. Prajitno dan R. Z. Awwal, "Pembuatan Dan Karakterisasi Prototipe Dye Sensitized Solar Cell (Dssc) Menggunakan Ekstraksi Kulit Buah Manggis Sebagai Dye Sensitizer Dengan Metode Doctor Blade," *Inst. Teknol. Sepuluh Nop.*, vol. 1, no. 2, hal. 73–78, 2013.

[8] S. Meliala, F. Manurung, R. Putri, dan T. Multazam, "Desain Model Parameter dan Monitoring Panel Surya Menggunakan IOT," vol. VIII, no. 1, hal. 4747–4759, 2023.

[9] D. Hastijsnti, "Pengaruh Perubahan Intensitas Matahari Terhadap Daya Keluaran Panel Surya.," 2015.

[10] D. N. Manurung, "Campuran Terhadap Efisiensi Kerja Dye Sensitized Solar Cell (Dssc)," 2021.

[11] T. X. a Yu Zhang a, Lingling Wang a b, Bingkun Liu a, Jiali Zhai a, Haimei Fan a, Dejun Wang a, Yanhong Lin a, "Synthesis of Zn-doped TiO2 microspheres with enhanced photovoltaic performance and application for dye-sensitized solar cells," vol. 56, hal. 6517–6523, 2011.

[12] R. Harahap dan Suherman, "Sistem Pendinginan Aktif Versus Pasif DiMeningkatkan Output Panel Surya," *J. Sain, Energi, Teknol. Ind.*, vol. 5, no. 2, hal. 79–87, 2021.