Musa Acuminata Bract extraction for dye sensitized solar cell fabrication with microwave irradiation

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Abstract. One of the problems encountered in the making of dye-sensitized solar cell (DSSC) is the efficiency still relatively small compared to the conventional solar cells made from silicon. In this study, microwave irradiation was used in the process of coating Musa Acuminata Bract extract, with the aim that more anthocyanin pigments absorbed in the work electrode. This anthocyanin can make more sun energy absorbed and enhances efficiency. The resulting Musa Acuminata Bract extract was characterized using Ocean Optic Vis-Nir USB 4000 to determine its optical properties and produce maximum absorbance of 1.7353 at mass fraction of 0.45. The irradiation process was carried out using Electrolux Microwave Oven (EMM 2308X) at 140 W. After the DSSC sandwich is arranged, the sample is characterized using an El-Kahfi 100 I-V meter to determine its electrical properties. DSSC without microwave irradiation has an efficiency of 0.000345%, while with microwave irradiation, it could yield efficiency of 7.26%. This proves that microwave irradiation can improve DSSC performance.

1. Introduction
Solar cells act as converters of solar energy into electrical energy. Based on the manufacturing material, solar cells consist of two types, namely silicon solar cells and non-silicon solar cells (Dye Sensitized Solar Cell / DSSC). DSSC is a solar cell that was first developed by Gratzel et.al, so it is also called Gratzel cells. The advantages of DSSC are that, used materials relatively cheap, and eco-friendly [1].

Organic materials that suit for solar cells are organic materials that contain color pigments such as anthocyanin, betalanin, and chlorophyll and their derivatives. This color pigment will be used as a dye sensitizer to receive solar energy in a solar cell. Several previous studies have been used color pigments, like anthocyanin in blueberry, chlorophyll in spinach leaves, and anthocyanin in hibiscus for solar cells [2-4].

In addition, there are other materials that can be extracted to be used as a dye (photosensitizer) for example the heart of a banana. Banana heart is one source of anthocyanin that indicated from its purple red color. Several studies on DSSC made from Musa Acuminata Bract extract have been produced using spin coating and spraying methods [5-7].

One of the problems in the development of DSSC is its small efficiency value and has not been able to reach the efficiency value of silicon-based solar cells. This is partly due to the small amount of
dye absorbed by the working electrodes. One effort to increase the amount of dye absorbed at the working electrode is by microwave irradiation. Microwave irradiation, known as a non-contact treatment technology, is allowed for the fast, precisely controlled, and selective heating without induced temperature gradient in different applications because of its working principle stemming from the oscillation of the dipoles under the external field [8-12]. These interesting results motivate us to explore the possibility of microwave irradiation on the adsorption of these dyes on TiO2, which remains missing but highly potential for promoting the productivity. Thus, we developed a facile, rapid, efficient sensitization route for controlling the adsorption of dye on TiO2 via microwave irradiation for the first time. Different from other dye adsorption approaches, this simple route can provide the possibility of effectively improving the utilization of costly dye and simultaneously integrating into the manufacturing with ease while achieving the required result of the dye adsorption in a short time [13].

The solar conversion efficiency (g) of a DSSC can be estimated using the conversion efficiency formula (1) [14].

$$\eta = \frac{P_{cell}}{P_{in}} \times 100\%$$  \hspace{1cm} (1)

where Pcell and Pin denote the maximum output power and the input power, respectively. Imax and Vmax are the photocurrent and photovoltage for the maximum power output (Pcell). P input uses a 50 Watt halogen lamp in a box without gap of 20x20x20 cm so as it produce an average input power of 125 mW / cm2. The first paragraph after a heading is not indented (Using Bodytext style).

2. Methods

The tools used in this research include measuring cups, beaker glasses, dropper drops, digital balance, petri dishes, ovens, hot plates, iron spatulas, digital multimeters, Electrolux Microwave Oven EMM 2308X, Vis-NIR USB 4000 ocean optical spectrometers, PerkinElmer Frontier FTIR Spectroscopy, IV-meter Nacrible 101, and CCD Microscope Scopeman MS-804. The materials used are Musa Acuminata Bract, Indium Titanium Oxide (ITO), methanol, acetone, ethanol, distilled water, filter paper, sticky tape, acetic acid, DI-water, PEDOT: PSS, ethylene glycol, activated carbon, aluminum foil, kapton tape, and carboxymethyl cellulose (CMC).

The sample consists of several layers with a design such as figure 1:

![Figure 1. DSSC Design](image)

Samples were made in 6 variations of the composition of the DSSC layer. Dye was made by extracting Musa Acuminata Bract. Musa Acuminata Bract extracts is made in 5 variations of mass fraction with the formula (2):

$$X = \frac{a}{a+b}$$  \hspace{1cm} (2)
X = mass fraction; a = *Musa Acuminata Bract* mass and; b = mass of the solvent.

The mass of the solvent for *Musa Acuminata Bract* extraction is 186 grams with a mass ratio = ethanol: distilled water: acetic acid = 150: 30: 6. The composition of *Musa Acuminata Bract* extract shown in Table 1.

**Table 1.** Composition of *Musa Acuminata Bract* Extract

| Mass Fraction | Solvent (g) | Banana Bract (g) |
|---------------|-------------|------------------|
| 0.25          | 186         | 62               |
| 0.30          | 186         | 79.7             |
| 0.35          | 186         | 100.15           |
| 0.40          | 186         | 124              |
| 0.45          | 186         | 152.18           |

Working electrodes were made differently in each sample to compare their effect on DSSC performance. The working electrodes are made with TiO$_2$, CMC, ethanol and acetic acid. The mass of the adhesive TiO$_2$ (CMC) varies between 2-3 grams as shown in Table 2.

**Table 2.** Composition of Ingredients for Making TiO$_2$ Paste

| Sample Code | TiO$_2$ Powder (g) | CMC (g) | Alcohol (ml) | Acetic Acid (ml) |
|-------------|--------------------|---------|--------------|------------------|
| B1          | 4                  | 2       | 10           | 0.4              |
| B2          | 4                  | 2.2     | 10           | 0.4              |
| B3          | 4                  | 2.4     | 10           | 0.4              |
| B4          | 4                  | 2.6     | 10           | 0.4              |
| B5          | 4                  | 2.8     | 10           | 0.4              |
| B6          | 4                  | 3       | 10           | 0.4              |

The working electrodes are made by depositing TiO$_2$ paste into ITO glass. TiO$_2$ paste is made by mixing TiO$_2$ and solvent using a heated magnetic stirrer at a speed of 1500 rpm for 1 hour [6]. TiO$_2$ paste was then deposited with a modified Doctor Blade technique. After deposition, the film is then heated at 120 °C for 20 minutes. The next process is the application of a dye to the working electrode by dripping. After that the work electrodes were irradiated with 2308X EMM microwave oven at 140 Watt power for ±15 minutes.

Counter electrodes are made by mixing activated carbon, CMC, and ethanol. After the carbon paste is formed, it is then deposited onto the ITO glass and heated at 180 °C for 1 hour [15]. *Musa Acuminata Bract* extract was characterized by the Ocean Optic Vis-Nir 4000 Spectrometer and FTIR to determine the optical properties. The working and counter electrodes were characterized by CCD Microscope MS-804 to determine the surface structure, and the DSSC sandwiches that were prepared were then characterized using a Nachtrieble 101 I-V Meter to determine electrical properties.

**3. Result and Discussion**

The absorbance of *Musa Acuminata Bract* extract is presented in Fig 2. In this study, variations in mass fraction were used to increase the content of anthocyanin pigment extracted in order to obtain greater DSSC efficiency values.
Figure 2. Absorbance of *Musa Acuminata Bract* Extract

To characterize this optical property used the Ocean Optic Vis-Nir 4000 Spectrometer. Based on the graph, it can be seen that the highest absorbance value is obtained by the sample with a mass fraction of 0.45 that uses the highest amount of *Musa Acuminata Bract* mass. In addition to optical properties, banana bract extract is also characterized using FTIR to determine the functional group of *Musa Acuminata Bract* extract. The results of the characterization using FTIR are presented in Fig. 3.

The functional groups of active chemical compounds in plant extracts can be identified based on the absorption peaks shown in the infrared radiation area. The FTIR spectra of the dyes from *Musa Acuminata Bract* showed almost similar functional group positions. A broad peak between 3000 cm$^{-1}$ to 3700 cm$^{-1}$ indexed to the O-H group from [16], absorption peak 1646.91 indicates C = O bond, absorption peak 1283.24 - 1388.42 cm$^{-1}$ indicates absorbance peak bond of C-H methyl bending vibration or C-O stretching vibration of hydroxyl groups and absorption peak 1062.76 cm$^{-1}$ shows the C = H aromatic bond [17].
The working electrodes characterized their surface structure using a CCD Microscope before and after the drops of *Musa Acuminata Bract* extract. Surface structure test used to determine the surface structure and homogeneity of the working electrode thin film. The results of surface structure characterization shown in Fig 4. & Fig 5.

![Image](image1.png)

**Figure 4.** Surface structure of thin film working electrodes before drops of extracts from the heart of the sample a) B1, b) B2, c) B3, d) B4, e) B5, and f) B6.

Based on Figure 4, it can be seen that the surface structure of the thin film working electrode looks rough. In samples B2, B5, and B6 the surface structure of the working electrode looks very thin, this is because TiO$_2$ deposited on the substrate slightly. Work electrodes that have been dripped with dye are coded C1-C6 as shown in Figure 5.

![Image](image2.png)

**Figure 5.** Surface structure of thin film working electrodes after *Musa Acuminata Bract* extract dropped, a) C1, b) C2, c) C3, d) C4, e) C5, dan f) C6.

![Image](image3.png)

**Figure 6.** Surface structure of thin film working electrodes after drops of banana heart extract samples a) by microwave irradiation, and b) without microwave irradiation.

After dropping with *Musa Acuminata Bract* extract, the surface of the film coated with *Musa Acuminata* Bract extract shown in Figure 5. The surface color which originally white turned yellowish.
In this study, two treatments given, namely extracts which dropped by Musa Acuminata Bract extract and then irradiated with microwave and not irradiated. The difference in the results of this treatment shown in Figure 6.

Based on Figure 6. It can be concluded that the addition of microwave irradiation can increase the absorbing of Musa Acuminata Bract extract at the working electrode, this is evidenced by the increasing thick brown color in Figure 6. a). Each layer of DSSC that has been made then arranged into DSSC according to the design in Figure 1. DSSC that has been arranged, then characterized using I-V Meter Nacribele 101 to determine the electrical properties. At the time of testing, a 50 Watt halogen lamp source was used in a box without a gap of 20 x 20 x 20 cm to produce an average input power of 125 mW/cm$^2$. I-V meter test results shown in Figure 7.

Based on the I-V meter curve can be calculated the value of efficiency of the Dye-Sensitized Solar Cell from Musa Acuminata Bract extract in table 3.

| Kode Sampel | Vmax (V) | Imax (A) $10^{-3}$ | Pcell (W/cm$^2$) $10^{-4}$ | $\eta$ (%) |
|-------------|----------|-------------------|-----------------|---------|
| C1          | 9.95     | 7.57              | 75.325          | 6.026   |
| C2          | 1.1      | 3.42              | 3.762           | 3.010   |
| C3          | 0.7      | 2.72              | 1.904           | 1.523   |
| C4          | 0.1      | 2.32              | 2.32            | 4.088   |
| C5          | 2.5      | 3.63              | 9.75            | 7.26    |
| C6          | 1.8      | 3.34              | 6.12 $10^{-3}$  | 4.81    |
| C6 without irradiation | 9.95 | 4.33 x 10$^{-8}$ | 43.0835 x 10$^{-8}$ | 0.000345 |

4. Conclusion
The highest efficiency is C5 sample that is 7.26%. There is a big difference between samples irradiated with microwave and non-irradiated samples. This is because the work electrodes irradiated by microwaves have a more porous TiO$_2$ structure so that the Musa Acuminata Bract extract which fills more pores. The more Musa Acuminata Bract extract absorbed on TiO$_2$ has an impact on the increasing performance of solar cells.
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