THE EFFECT ON EXTRACTING SOLVENTS USING NATURAL DYE EXTRACTS FROM *HYPHAENE THEBAICA* FOR DYE-SENSITIZED SOLAR CELLS

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Abstract

This study covers the fabrication and characterization of dye sensitized solar cell using *Hyphaene Thebaica* as the natural dye sensitizer for DSSCs. Ethanol and water in separate container was used as the extracting solvent for the natural dyes. Titanium dioxide (TiO_2) was deposited on fluorine doped tin oxide(FTO) conductive glass forming a TiO_2 thin film, underwent sintering at 400 °C for 40 minutes. The photo electrochemical performance of the dye sensitized solar cell (DSSC) based on the doum palm pericarp shows open circuit voltage (V_{oc}) of 0.37 V and 0.50 V, and short circuit current density (J_{sc}) of 0.005 mA/cm^2 and 0.010 mA/cm^2 for ethanol and water extracts respectively. This study further inspected the fill factor as 0.63 and 0.66 for the ethanol and water extract respectively. The conversion efficiency for the ethanol extract was 0.012 % and water extract is up to 0.033 % under light intensity of 1000 m/Wm^2 (AM 1.5).

Keywords: Dye-sensitized solar cell, Hyphaene Thebaica, doum pericarp, titanium dioxide.

1.0 **Introduction**

Energy technology is one of the most important technologies in the 21st century that dominated people's life and people's consumption. Moreover, environmental pollution has increasingly become a worldwide concern in the past few decades. Thus, how to enhance the efficiency of natural energy use and to recycle regenerated energy has become an important research field for developed countries (Chang *et al*., 2011).

Dye-sensitized solar cells (DSSCs) have been widely investigated as one of the next-generation solar cell because of their simple structure and low manufacturing cost (O'regan and Gratzeal, 1991). Generally, DSSC comprises of a nanocrystalline titanium dioxide (TiO_2) electrode modified with a dye fabricated on a transparent conducting oxide (TCO), a platinum (Pt) counter electrode, and an electrolyte solution with a dissolved iodine/triiodide ion redox couple between the electrodes (Chiba *et al*., 2006). Although certified conversion efficiency using black dye has been reported to be 10.4% by the Swiss Federal Institute of Technology in Lausanne (EPFL) (Nazeeruddin *et al*., 2001). It is well known that the conversion efficiency (η) of solar cells can be represented as follows (Kimpa *et al*., 2012)

$$\eta = \mathrm{FF} \times I_{sc} \times V_{oc} / P_{in} \qquad (1)$$

where FF, I_{sc}, V_{oc}, and P_{in} are fill factor, short circuit current, open circuit voltage, and incident power, respectively.

Organic dye have higher absorption efficient used for DSSCs with efficiencies of up to 9% have been reported (Hara *et al*., 2004). Organic dyes with high absorption coefficient could translate into thinner nanostructure metal oxide film. This advantageous of transporting charge both in the metal oxide and in the permeating phase, allowing for the use of higher viscosity materials such as ionic liquids, solid electrolytes or holes conductors.

In nature, some fruits, flowers, leaves and so on show various colors and contain several pigments that can be easily extracted and then employed in DSSCs. The leaves of most green plants are rich in chlorophyll and the application of this kind of natural dye has been frequently investigated in many related studies. Anthocyanins are natural compounds that give color to fruits and plants and are also largely responsible for the purple–red color of autumn leaves and for the red color of flower buds (Chang and Lo, 2010).

Kimpa used the extract of flame tree flower and pawpaw leaf as photosensitizer and the open-circuit voltage (V_{oc}) of fabricated DSSCs is 0.51 V and 0.50 V (Kimpa *et al*., 2012). Zhu investigated the extract of frozen blackberries to serve as photosensitizer and the open-circuit voltage (V_{oc}) of fabricated DSSCs is 0.33 V (Zhu *et al*., 2008). Polo extracted the blue violet anthocyanin of Jaboticaba and Calafate respectively to serve as photosensitizer and the V_{oc} of prepared DSSCs is 0.59 V and 0.4 V respectively (Polo *et al*., 2006). Furukawa investigated the extract of red-cabbage, curcumin and red-perilla to serve as natural dye sensitizers for DSSC and the V_{oc} is 0.52 V, 0.53 V and 0.49 V respectively. Patrocinio adopted the extract of blueberries and Jaboticaba's skin to serve as photosensitizer and the V_{oc} of prepared DSSCs is 0.59 V and 0.45 V respectively (Patrocinio *et al*., 2009). In this paper, extracts of doum pericap was used as the natural dyes as dye-sensitizers for the preparation of DSSCs.

2.0 **Experimental**

Doum fruit was peeled and the pericarp was used as the natural plant. The doum pericarp was crushed with a porcelain mortar and pestle, the crushed sample were kept on two different conical flask. The samples were mixed separately with 50 cm^3 of ethanol (99% absolute) at room temperature and 50 cm^3 of distilled water in a dark room. The solution were filtered separately using filter paper to acquire a pure and natural dye solution. The TiO_2 film was prepared by blending 0.2 g of commercial TiO_2 powder (Degussa, P25), 0.4 cm3 of nitric acid (0.1 M), 0.08 g of polyethylene glygol (MW 10,000) and one drop of a Triton x-100 (a nonionic surfactant). The mixture was well mixed using an ultrasonic bath for 1 h and the resulting paste was spread over an FTO conductive glass plate (SOLARONIX) having 15 Ω/cm^2. TiO_2 pastes were deposited on the FTO conductive glass by rigid squeegee and screen printing procedure (polyester mesh of 90) in order to obtain a TiO_2 film with a thickness of 9 μm. The active area of DSSC was 1.04 cm^2 (1.3 cm × 0.8 cm). The TiO_2 thin film was sintered at 450°C for 45 minutes to increase compact- ness of the thin film. The TiO_2 film was consolidated through heat treatment, increasing the internal voids of film organization and thus enhancing its absorption performance. Then the sintered TiO_2 thin film was immersed for 24 h in the natural dyes prepared, allowing the natural dye molecules to be adsorbed on the surface of TiO_2 nanoparticles. Anhydrous alcohol was used to remove any natural dye that had not been adsorbed on the surface of TiO_2 nanoparticles. DSSCs were assembled following the procedure described in the literature (Kimpa *et al*., 2012), the catalyst-coated counter electrode was placed on the top so that the conductive side of the counter electrode faces the TiO_2 film. The iodide electrolyte solution (0.5M potassium iodide mixed with 0.05M iodine in water-free ethylene glycol) was placed at the edges of the plates. The liquid was drawn into the space between the electrodes by capillary action. Two binder clips were used to hold the electrodes together. In the performance test of the prepared DSSC, xenon (Xe) light of 1000 W was selected to simulate sunlight (AM 1.5), and an I-V curve analyzer (Model 4200 SC) was employed to measure the photoelectric conversion efficiency of the prepared DSSC. The measured results were plotted on I-V curve.

3.0 **Results and Discussion**

Figure 3.1 shows the absorption spectra of doum pericarp dye extracts and doum pericarp dye extracts adsorped on TiO_2 surface using ethanol and distilled water as our extracting solvent. Absorption spectra provide necessary information on the absorption transition between the dye ground state and excited states and the solar energy range absorbed by the dye. The absorption range of doum pericarp dye extracts adsorbed on TiO_2 was found within the range of 300 – 450 nm. Doum water extract has two absorption peaks at 350 nm and 400 nm, while the absorption peak of the doum ethanol extract adsorped on TiO_2 was only at one absorption peak of 353nm. It can be seen that after TiO_2 nanoparticles was added to doum pericarp extract, its absorption intensity decreases from 440 nm to 350 nm. This property reduces the charge transfer ability of the fabricated DSSCs under normal sunlight thereby reducing the efficiency. The dye pigments belongs to the existence of chromophores and it represents the chemical group that is responsible for the colour of the molecule, that is its ability to absorbed photon.. Conjugation of chromophores makes them absorb light of different wavelength and energy. Peak wavelength tend to be shifted towards long wavelength as the size of conjugated system or chromophores increases. The double or two absorption peaks of the doum pericarp dye extracts with distilled water as extracting solvent could be due to the presence of complex chromophores conjugated with other group of chromophores. Figure 3.2 compares the absorption spectrum of doum pericarp ethanol extract and doum pericarp distilled water extract.

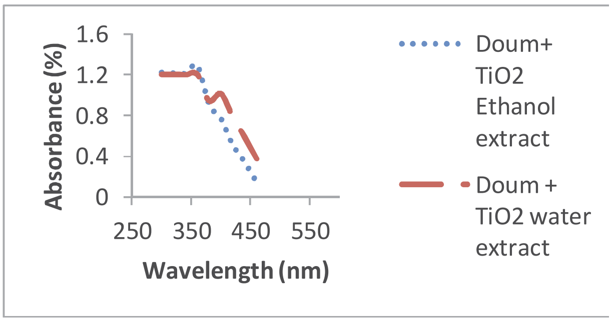

Fig. 3.1 Absorption spectra of doum pericarp with TiO2 dye extract using ethanol and water as extracting solvent.

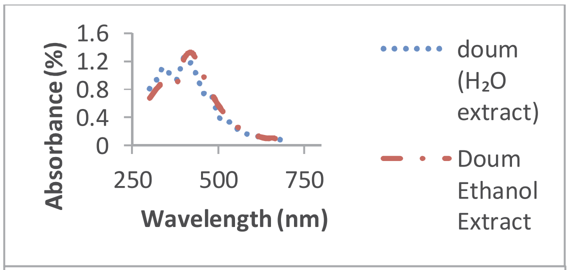

Fig. 3.2 Absorption spectra of doum pericarp liquid dye extract using ethanol and water as extracting solvent.

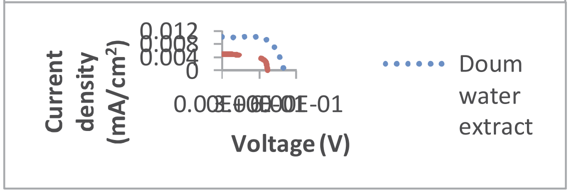

Fig. 3.3 I-V characteristics of DSSC sensitized by natural dyes extracted from doum pericarp (*Hyphaene Thebaica)*

The dye sensitization effect was demonstrated with a DSSC using natural dye from doum pericarp and characterized by current – voltage measurements in figure 3.3. Energy conversion efficiency of 0.012% at about 0.1mW/cm^2 solar illumination was obtained from the dye extracts using ethanol as the extracting solvent while 0.033 % efficiency was obtained for the dye extract using water as the extracting solvent. Table 1 shows the data acquired from measuring the photoelectric conversion efficiency of the DSSCs. From the result obtained, It was observed that using ethanol as our extracting solvent has better absorption capability than water. In this research work the efficiencies of the cells are both very low.

Table 1. Photoelectrochemical parameters of the DSSCs sensitized by natural dyes extracted with water in the UV-vis light range.

Dye	**Jsc (mAcm^{-2})**	**Voc (mV)**	**FF**	η %
Doum pericarp (ethanol extract)	0.005	0.37	0.63	0.012
Doum pericarp (distilled water extract)	0.010	0.50	0.66	0.033

4.0 **Conclusion**

The absorption range of the dye and the dye adsorbed on TiO_2 using ethanol and water as the extracting solvent are within the wavelength of 300 nm, 440 nm. The absorption range for pure dye is between 300 nm – 600 nm as shown in figure 3.2. The power conversion efficiency η of the DSSC using doum pericap ethanol extract is 0.012 % while that of distilled water as the extracting solvent is up to 0.033% . DSSC efficiency from doum pericarp extract has a very low efficiencies compared to that obtained by Zhu *et al*., (2008), Kimpa *et al*., (2012), Polo *et al*., (2006) and Furukawa *et al*., (2009). The poor performance of the cell could be linked with various factors, one of which could be the dye used and the ability of the electron transportation to the conduction surface of the TiO_2.

5.0 Acknowledgment

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