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Research Article

Study of the Effect of Extraction Solvents on the Optical Activity of *Mussaenda erythrophylla* and *Bougainvillea spectibilis*

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Abstract

Five different solvents; acetone, ethanol, distilled water, hydrochloric acid (HCl) and acidified ethanol were used as extraction solvents to study the optical sensitivity of *Mussaenda erythrophylla* and *Bougainvillea spectibilis* for dye sensitized solar cells (DSSC) applications. The natural dyes were extracted using cold extraction method. Optical characterization was carried out with the 3600 UV/Vis spectrophotometer within the range of 350-1020 nm. It was observed that the five dye extracts of *Mussaenda erythrophylla* showed wide absorbance within the visible spectrum with the extract of acetone having the highest absorbance at 390 nm and the extract of water showing a peak at 440 nm. It also showed the highest transmittance in the visible region though it dropped to zero at 425 nm but rises again. Extracts of distilled water, acetone, and acidified ethanol showed good peaks of reflectance within the visible spectrum. Acetone dye extracts of *Bougainvillea* showed the highest peaks at 400, 460 and 560 nm. The five extracts of *Bougainvillea* showed good transmittance up to the near infra red region. All the dye extracts showed appreciable absorbance within the visible region and are therefore possible antennae for DSSCs applications.

Keywords: Antena; Optical Antenna; Solvents; Spectrophotometry

Introduction

Generation of electricity through illumination of organic dyes in electrochemical cells was discovered in the late 1960s [1]. This discovery has attracted huge scientific and technological interest toward the development of Dye Sensitized Solar Cells (DSSCs) [2,3]. DSSC employs dyes to absorb light from the sun and converts it into electrical energy [3-5]. The organic dyes which are renewable and eco-friendly have been intensively studied with a focus on increasing the extinction coefficient and extending the optical absorption spectrum.

Solvents used in the extraction of dyes among other factors have effect on the photoactivity of solar cells [6,7]. The extraction solvent pulls apart the solute's molecules and eventually the solute's molecules become evenly distributed throughout the solvent [4,8-12]. However, there are three main types of extraction methods namely: Aqueous extraction, cold extraction and soxhlet extraction method. Aqueous extraction is a process of extracting dyes from plant or other material using distilled or deionized water. Cold extraction as the name implies involves the use of cold organic or inorganic solvents such as methanol, ethanol, chloroform and so on, for extraction. Sometimes the solvent can be used without diluting it in any other solvent to extract dye. Soxhlet extraction is the process of extracting dyes using a matrix and the extraction solvent is being cycled continuously through the matrix by boiling and condensation, with the sample being collected in the hot solvent [13,14]. Cold extraction method is the cheapest of all the extraction methods. The method also involves minimal exposure to heat thereby preserving photochemical content which results in higher quality of dye samples.

However, efforts have been made to increase the optical properties of solar cells by doping the wide band gap (3.2eV) titanium (iv) oxide with dyes. Doping refers to the introduction of some impurities (dopants) to the material for the purpose of modifying its physical properties or electrical characteristics. A dopant may increase the level of the valence band (VB) edge or lower the conduction band (CB) level, and depending on the nature of dopant, whether it is a metal/nonmetal or organic/inorganic dye, thus reduces the band gap. It improves or minimizes electron–hole recombination, so as to minimize any loss in quantum yield [6,15]. The inorganic dyes are expensive, not environmentally friendly, not renewable and not readily available but the organic or natural dyes as photosensitizers are very attractive because they are of low cost, abundant in supply, and sustainable [16-19] extracted dye from *curcuma longa* (Tumeric) using acetone, ethanol and methanol as extraction solvents under the same experimental conditions and came up with the following absorbances 440 nm, 480 nm and 456 nm respectively. Merkhan *et al.*, used distilled water as an extraction solvent for *carrisacaranda* and observed a peak absorbance at 520 nm. Khairudin *et al*., used acidified methanol to extract dye from shoe flower and a peak absorbance of 638 nm was recorded. Significantly, Trial and error has been the criterion for selection of the solvent [20-22]. Currently, different parts of plant pigments such as the flower petals, leaves and bark have been tested as sensitizers [23]. The nature of these pigments together with other parameters has resulted in varying performance in materials [17,23]. Researchers have indicated that the use of natural ruthenium dye, cynodon dactylon, sepia melianin among other dyes which are cheap, abundant, renewable and ecofriendly have significantly modified the photoactivity of titanium dioxide.

This research work aims at investigating the effect of five different extraction solvents on absorbance, transmittance, reflectance of two novel natural dyes from *Mussaenda erythrophylla* and *Bougainvillea spectibilis*. The findings will contribute to a pool of knowledge for application and further research in DSSC technologies. This study will help researchers understand the efficacies of using different dopants as photosensitizers which are not poisonous, not costly and readily available.

Materials and Methods

Preparation

The flower samples of *mussaenda erythrophylla* were collected, washed and air dried until they became invariant in weight. 1.5g of each of the flower samples was measured separately into five (5) different containers. 100 ml of the extraction solvents were prepared according to the required percentage and concentration needed. 1% ethanol, 1% acetone, 0.01mol HCl, distilled water and ethanol mixed with HCl in the ratio of 99:1.were measured into five different containers and the flower samples were soaked into the extraction solvents. They were allowed to stand in a dark container for forty-eight hours. The cold extraction method was used to extract the dye samples and they were taken to the laboratory for characterization without further purification.

Characterization

Absorption spectra were recorded for *bougainvillea spectibilis*, *mussaenda erythrophylla* and *celosia argentae* using the 3600 UV/Vis spectrophotometer in the wavelength range of 380 nm-1020 nm. The transmittance was calculated using equation (1) by [24,25].

$T = 10^{-A}$ (1)

The reflectance value was deduced from equation (2) according to [15].

Reflectance $R = 1 - (A + T)$ (2)

Result and Discussion

The optical properties of the various dye extracts of *mussaenda erythrophylla* and *Bougainvillea spectibilis* were studied using the five (5) different extraction solvents.

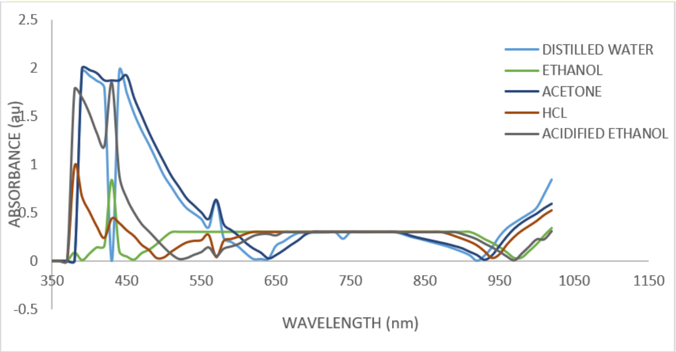

Figure 1: Absorbance plot of *mussaenda erythrophylla* with various solvent.

Absorbance	Acetone	Acidified ethanol	Ethanol	HCl	Distilled water
1.99 au	390 nm	-	-	-	-
1.95 au	410 nm	-	-	-	440 nm
1.84 au	440 nm	430 nm	-	-	450 nm
0.5 nm	385 nm	375 nm	430 nm	400 nm	540 nm

Table 1: Absorbance of *mussaenda erythrophylla* with various solvent.

Figure 1 and Table 1 show the absorbance of *mussaenda erythrophylla* with the various extraction solvents. Acetone extract shows the highest peak absorbance at 390nm. This shows that acetone extract is applicable to solar blind cells, because they absorb well within this region. Distilled water extract has it's highest absorbance at 440nm. Acidified ethanol show a higher peak absorbance at 430nm than ethanol extract at the same wavelength. This is probably due to the fact that dye extract at a pH of 3 displays broad absorption peak resulting from π - π* transitions. Acetone and distilled water extract showed wider absorbance spectra within the visible spectrum. Acidified ethanol show a wider spectrum than ethanol with HCl showing the least absorbance in the higher visible region. These absorbance behaviors indicate good optical property for *mussaenda erythrophylla*.

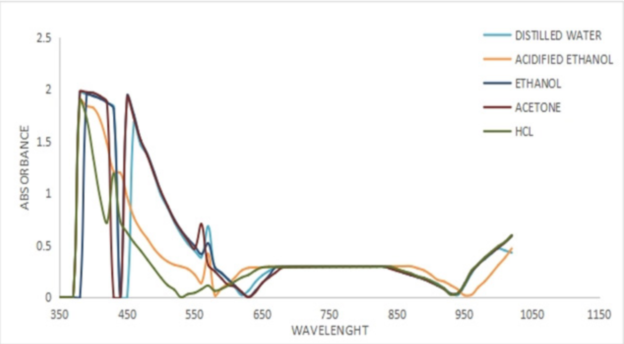

Figure 2: *Bougainvillea spectibilis* absorbance graph with different solvents.

Peak Absorbance	Acetone	Acidified ethanol	Ethanol	HCl	Distilled water
1.99 au	400 nm	-	-	-	-
1.95 au	460 nm	380 nm	450 nm	-	390 nm
1.84 au	-	-	-	390 nm	
0.7 nm	560 nm	-	-	-	
0 nm	430 nm	450 nm	-	530 nm	-

Table 2: Absorbance of bougainvillea spectibilis with different solvents.

Figure 2 and Table 2 above show absorbance of Bougainvillea *spectibilis* with different extraction solvents. Dye extract of acetone shows a strong peak at 400 nm, zero absorbance at 430 nm, a secondary peak at 460 nm and another peak at 560 nm. The variation in absorbance at different wavelengths. can be explained by the presence of different pigment that absorb light differently. Peak absorbance at 400 nm suggest the presence of anthocyanins, while the zero absobance at 430 nm suggest that there might be probably no pigment in the dye extract that absorbs within the green region of the spectrum Dye extract of HCl showed a peak at 390 nm but went to zero at 530 nm before a very slight increase was recorded. Distilled water and acidified ethanol had their maximum peak absorbance from 380-390nm, ethanol had its peak absorbance of 1.952au at 450nm. This result is in full agreement with the previous study by [26].

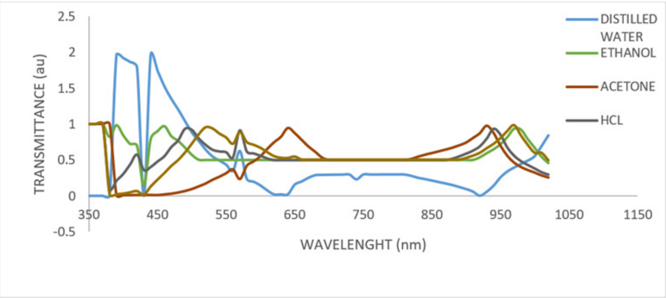

Figure 3: Transmittance plot of mussaenda with different solvent.

Dye Extracts	
Distilled water dye extract of *mussaenda erythrophylla* has the highest peak transmittance at 390nm and a secondary peak at 440nm with a wider spread of transmittance up to the higher visible region.	This shows that distilled water extract of the dye transmit light very well within the visible spectrum and will lend good application to highly reflective devices.
Ethanol shows a peak at 390 nm and secondary peak at 460 nm.	Ethanol extract show different transmittance due to the presence of different pigments that transmit light very well within those spectra
Acidified ethanol shows peaks at 530 nm and 970 nm at the near infrared region. Acetone shows peaks at 640 nm and 930 nm.	The presence of different compound or pigments like the flavanoids, anthocyanins and others could be the reason for the different transmittances. This shows good prospect for highly reflective devices
Distilled water dye extract shows the best transmittance among the other ones	

Table A

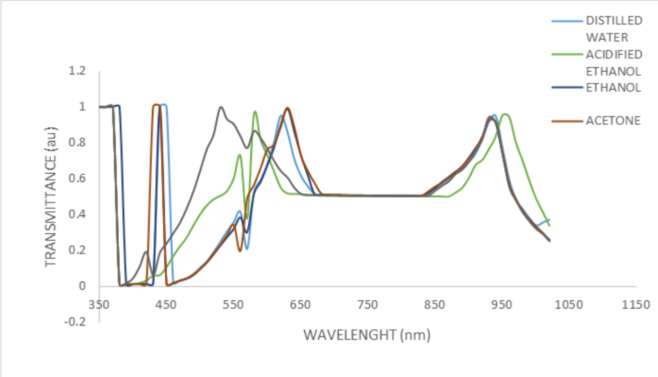

Figure 4: Bougainvillea transmittance graph with different solvents.

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From Figure 4 Dye Extracts	
Figure 4 shows extract of distilled water with a peak at 450 nm while ethanol and acetone extracts show equal peak at 440 nm	This shows that distilled water tranmsmits light at a higher wavelength than ethanol and acetone
Dye extract of HCl shows peak at 530 nm, acidified ethanol shows a primary peak at 560 nm and a secondary peak at 590 nm. Between 680 to 840 nm all the extract have the same transmittance values.	This transmittance is an indication that these extracts are good for high reflective devices
All samples show wide transmittance spectra at higher visible region with HCl showing the widest transmittance spectra.	This shows that HCl has a better transmittance prospect with Bougainvillea dye extract

Table b

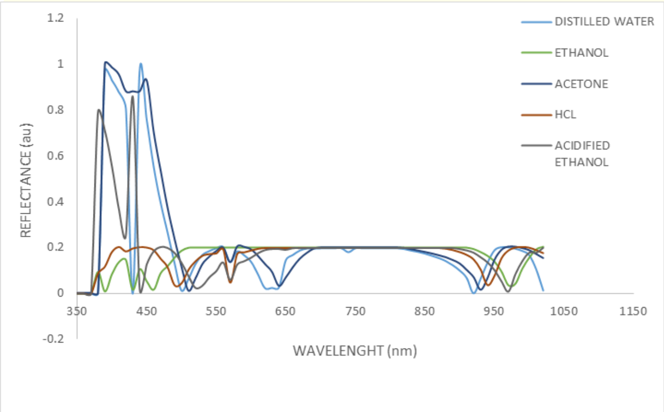

Figure 5: Reflectance plot of mussaenda with different solvent.

From Figure 5 Dye Extracts	
Dye extract of acetone shows the best peak of 1.0 a.u at 390 nm while the dye extract of distilled water indicates a peak of 0.978 au at 440nm	These reflectance values show that the extracts do not reflect well within the green spectrum
Acidified ethanol showed peaks at 380 and 430 nm while HCl and ethanol dye extract show very low reflectance	The reflectance values are not high
All the dye extract of *mussaenda* show very low reflectance at higher visible spectrum even up to the near infrared region	These results show that all the extracts are not very good for high reflective devices

Table c

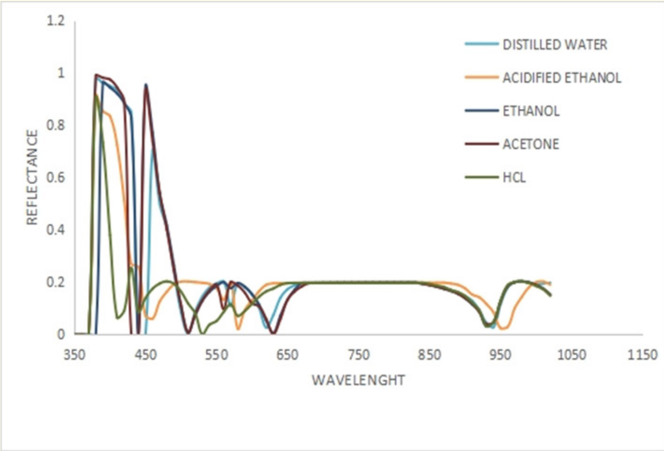

Figure 6: Bougainvillea reflectance graph with different solvents.

From Figure 6 Dye Extracts	
All the dye extracts show very high peak within the visible region with the extract of acetone showing a peak of 0.989 a. u. at 380 nm while ethanol and distilled water show peak at 390 nm	These dye extracts show low reflectance and are not applicable for high reflectance devices
HCl and acidified ethanol extract show peak at 380 nm	These dye extracts show low reflectance and are not applicable for high reflectance devices
All samples show lower reflectance at higher visible spectrum and NIR region	

Table d

Conclusion

Natural dyes were extracted from *Mussaenda erythrophylla* and *Bougainvillea spectibilis* with five different solvents; acetone, ethanol, distilled water, hydrochloric acid (HCl) and acidified ethanol using the cold extraction method. The effect of the extraction solvents on the optical activities of the dye extracts were investigated. It was observed that the five dye extracts of *Mussaenda erythrophylla* showed wide absorbance within the visible spectrum with the extract of acetone having the highest absorbance at 390 nm and the extract of water showing a peak at 440 nm, they also showed high transmittances within the visible region. The five extracts of *Bougainvillea spectibilis* also showed good absorbance within the visible spectrum with the dye extract of acetone showing the highest peaks at 400, 460 and 560 nm. All the dye extracts showed good optical qualities however, the extract of acetone showed the best optical qualities among the other extracts. This makes acetone a better extraction solvent for the dyes of *Mussaenda erythrophylla* and *Bougainvillea spectibilis*

Acknowledgement

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