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# Application of Hibiscus Sabdariffa and leaves of Azardirachta Indica calyxes as sensitizers in Dye-sensitized solar cells

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**Abstract:-** In this study we explored the application of Hibiscus sabdariffa and leaves of Azardirachta Indica calyxes methanolic extracts as sensitizers in Dye-sensitized solar cell (DSSCs). The absorptions of the extracts were determined at different wavelengths (350-1000nm) and the effects of changing pH of the extract solution are also reported. The obtained values for Hibiscuss sabdariffa are solar energy conversion efficiency 0.002 %, fill factor 0.739, current density 4.5mA/cm-² and $V_{oc}$ 0.0124mV.For Azardirachta Indica conversion efficiency is 0.00017 %, fill factor 0.4, current density 2.5mA/cm-² and $V_{oc}$ 0.0118mV. We notice that the Fill Factor and solar energy conversion efficiency of Hibiscuss sabdariffa extract are higher than that of Azardirachta indica sensitized solar cell. This might be due to the abundance presence of anthocyanins in Hibiscuss sabdariffa, bonding of anthocyanins molecules with Titanium dioxide and minimal internal looses in the junction of the cell. The adjustment of extracts pHs from normal to acidic as significant effect on the absorption maxima of the extracts.

**Keywords:-** Methanol, Titanium dioxide, Hibiscus sabdariffa, Azardirachta Indica calyxes, Dye-sensitized solar cell

## I. INTRODUCTION

Dye-sensitized solar cells (DSSCs) are the third generation of photovoltaic device for the conversion of visible light to electrical energy. These new types of solar cells are based on the photosensitization produced by the dyes on wide band gap mesoporous metal oxide semiconductors; this sensitization is produced by the dye absorption of part of the visible light spectrum [18].

The use of natural pigment as sensitizing dye for the conversion of solar energy to electricity is very interesting because, on one hand they enhance the economical aspect and on the other, produce significant benefits from the environment point of view. Natural pigments extracted from fruits and vegetables, such as chlorophyll and anthocyanins, have been extensively investigated as DSSCs sensitizer [14]. The sensitization of wide band gap semiconductors using natural pigments is usually ascribed to some organic pigments [2], like anthocyanins and anthraquinones extracted from the leaves, flowers or other parts of the plant.

The field of DSSC research gained significant worldwide interest after [5] reported the use of a Ruthenium-based dye to achieve higher efficiency in a cell made of $TiO_2$ nanoparticles [15]. They achieved a major improvement in solar energy conversion efficiency of 11% in a dye-sensitized $TiO_2$ (anatase) thin-film solar cell [5]. This accomplishment was demonstrated in a PEC device consisting of a nanocrystalline and mesoporous $TiO_2$ (anatase) thin-film electrode sensitized by a stable Ru-terpyridine complex dye in non-aqueous solvent. Studies of low-temperature fabrication of $TiO_2$ on a flexible conductive film were investigated to realize a high-speed and low-cost manufacturing process of DSSC modules.

In the dye sensitized solar cells light absorption and transport are separated, unlike the other where the light is absorbed by a sensitizer which is anchored to the surface of a wide band semi conductor [16].Charge separation takes place at the interface via photo induced electron injection from the dye into the conductor band of the semi conductor to the charge collector [7],[13], [4],[8] and [12].

DSSCs exhibit energy conversion compatible to a-Si thin-film solar cells of about 10% but can be produced at much lower cost because of the application of inexpensive materials and the relative ease of the fabrication processes [9] and [3].The performance of the cell mainly depends on a dye used as sensitizer, the absorption spectrum of the dye and the anchorage of the dye to the surface of $TiO_2$ [11] and [17].

In this study we prepared DSSCs using natural dyes extracted from the calyxes of H**ibiscus**. sabdariffa and leaves of Azardirachta Indica. This study was borne out of the availability of these plants' parts in Nigeria and reports have shown that H**ibiscus** sabdariffa is rich in anthocyanins. Another important factor is that Nigeria uses about 3 trillion Kwh of energy each year, and with energy requirement growing every year, it is imperative to develop energy harvesting technologies from renewable energy sources for a sustainable future. More so that solar energy is abundant on earth but efficient and economical energy harvesting technology needs to be developed. Hence, it is necessary that devices like dye-sensitized solar cells are produced even at commercial scale to help meet Nigerians electricity and energy demand.

## II. METHODOLOGY

### 2.1 Sample source and preparation

Samples of the calyxes of H**ibiscus** sabdariffa and Azardirachta Indica leaves were obtained from Adiyah Farm, Ottah Ogun State, Nigeria. The samples were air dried and the dried samples were pulverized with the aid of mechanical blender (liquidizer). 50g of each pulverized sample was weighed using OHAUS Electronic weighing balance model brain weight B1500 made in USA and soaked in 500ml acidified methanol. The extracting solvent and the mixture were placed in an orbital shaker (SLAUART SSL1 ORBITAL SHAKER at 25rpm ) for 12 hours .The extract of each of the samples were decanted to remove the residual part of the samples. Simple distillation was carried out at $65^0$C in order to concentrate the dye of the samples. The Jenway pH meter model 3505 was use to determine the pH of extracts.

### 2.2 Preparation and construction of cells

We used conductive FTO glass ordered from Hartford Glass Company USA with dimension of 2.5 X 7.6cm (1"X3") and 2mm in thickness. The photo anode was prepared using two slides of the conductive FTO glass. A digital multimeter was used to check the conductive side of the FTO glass and the value is 32 Ω. Adhesive –tape are applied to the face of the conductive glass plate in order to create on opening of dimension 1.5 x 1.5cm$^2$ at the centre of the glass The cells were assembled and tested using the method reported by [1].

### 2.3 Measurement of photoelectric conversion efficiency of DSSC

The absorption spectra of dye solutions and dyes adsorbed on $TiO_2$ surface were recorded using a VIS Spectrophotometer (Spectrumlab 23A GHM Great Medical England). Solar energy conversion efficiency [the photocurrent voltage (I-V curve)] was measured by using digital multimeters under illumination of sunlight. Based on I-V curve, the fill factor (FF) is defined as

$$FF = (I_{max} X\ V_{max})/(I_{sc} X\ V_{oc}) \quad (1)$$

where $I_{max}$ and $V_{max}$ denote the maximum output power current and voltage respectively, and $I_{sc}$ *and* $V_{oc}$ denote the short circuit current and open-circuit voltage respectively. The overall energy conversion efficiency (η) is defined as,

$$\eta = (I_{sc}\ x\ V_{oc}\ x\ FF)/P_{in} \quad (2)$$

where, $P_{in}$ is the power of incident light.

## III. RESULTS AND DISCUSSION

The absorption spectra for the extracts of H**ibiscus** sabdariffa and Azardirachta indica are presented in Figures1 to 6. The depression shown in the figures are due to the fluctuating rate of election injection by the dye to the semi conductor which in turn depends on the dye structure. The former has optimal absorbance at 500nm, for the three pH variants, while the latter has its optimal absorbance in the range of 400– 450nm. This indicates that extracts of H**ibiscus** sabdariffa can be applied as an organic sensitizer in DSSCs; since this peak wavelength falls within the visible spectrum, and has better applicability as DSSC than Azardirachta indica. The normal pH of H**ibiscus** sabdariffa is 3.07 and 5.08 for Azardirachta indica. The absorbance maxima of the extracts at various pHs values decreases with decrease in pHs for Azardirachta indica and increases as pH decreases for H**ibiscus** sabdariffa. This difference in the two extracts is because of the chemical adsorption of the dye. In both cases Figure 7 and 8, the I-V curve showed a hump, which is an unstable I-V behavior. Such unstable I-V behaviors indicate that the diffusion of electrolyte is not so fast to deliver adequately charges for the regeneration of oxidized dye molecules [11] this result in a significant reduction of photocurrent i.e. the generation of photocurrent becomes limited by diffusion of electrolyte. We notice that in Figure 9 the XRD patterns exhibited strong diffraction peaks at $2^o$ indicating $TiO_2$ in the anatase phase and not in the amorphous phase.

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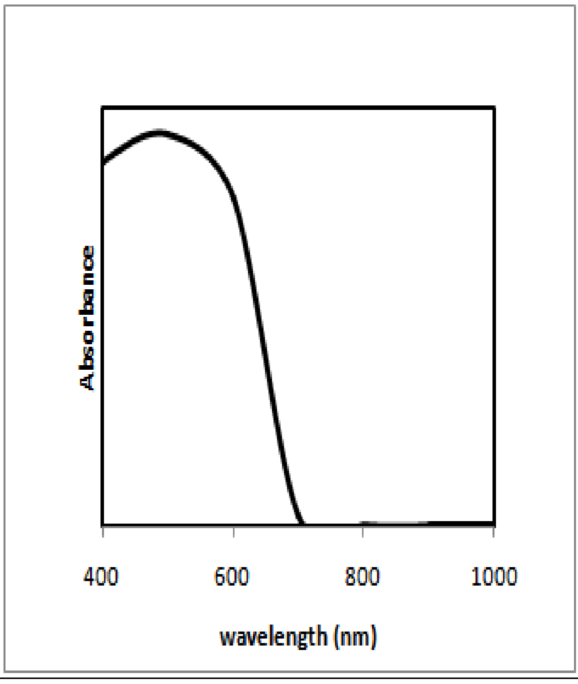


Fig. 1: Absorption of Hibiscus sabdariffa at pH 3.07

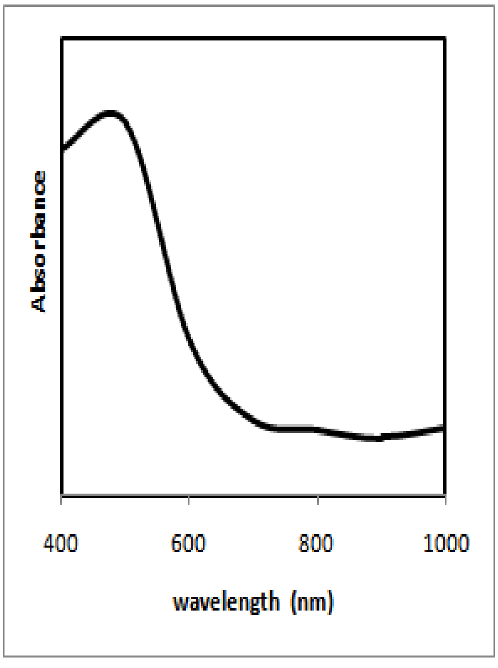


Fig. 2: Absorption of Hibiscus sabdariffa at pH 3.0

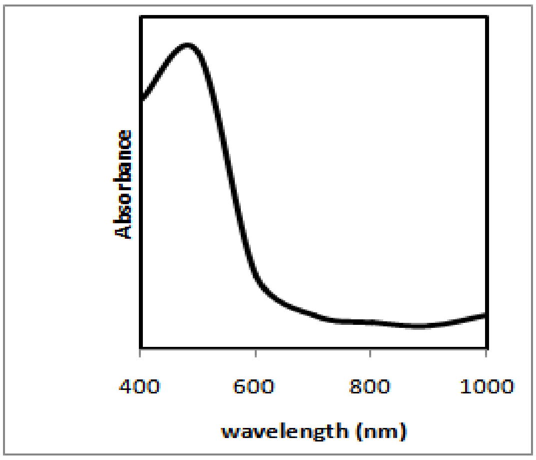


Fig. 3: Absorption of Hibiscus sabdariffa at pH 1.0

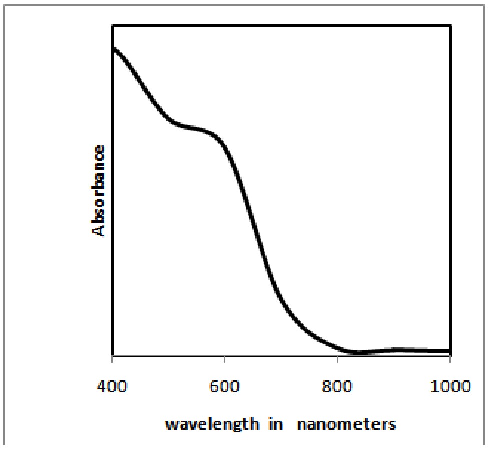


Fig. 4: Absorption of Azardirachta indica at pH 5.8

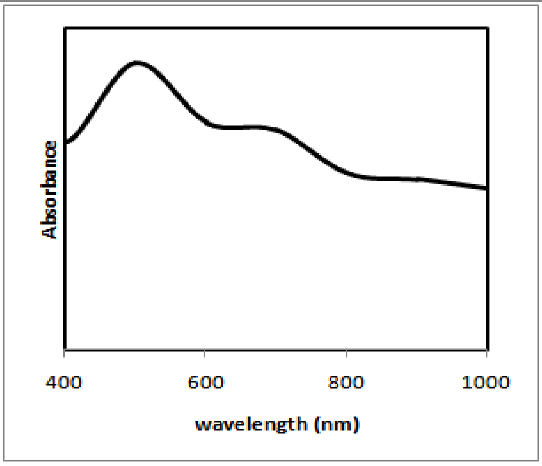


Fig. 5: Absorption of Azardirachta indica at pH 3.0

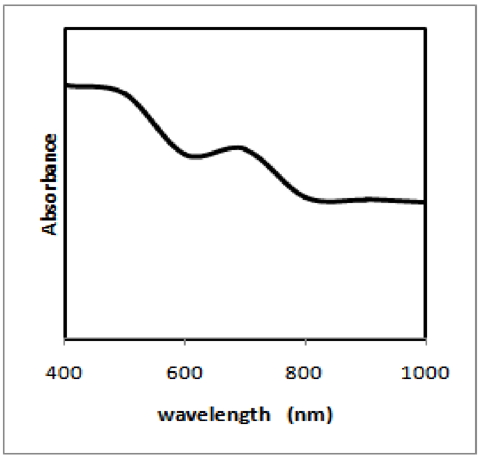


Fig. 6: Absorption of Azardirachta indica at pH 5.08

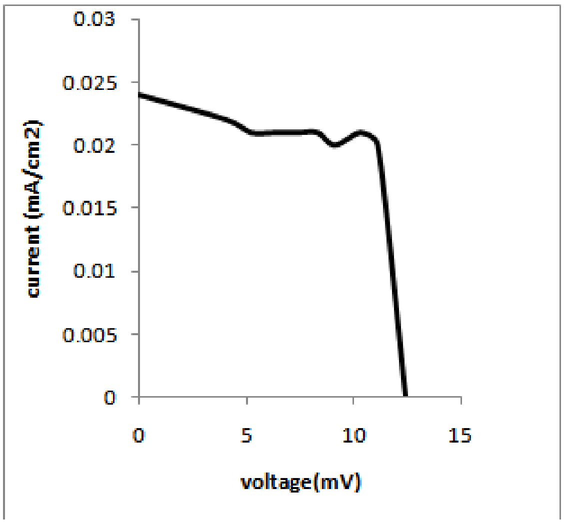


Fig. 7: I-V curve for solar cells fabricated with Hibiscus sabdariffa extract

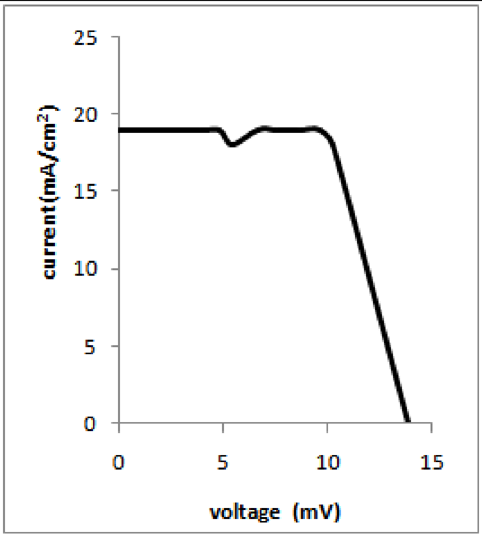


Fig. 8: I-V curve for solar cells fabricated with Azardirachta indica extract

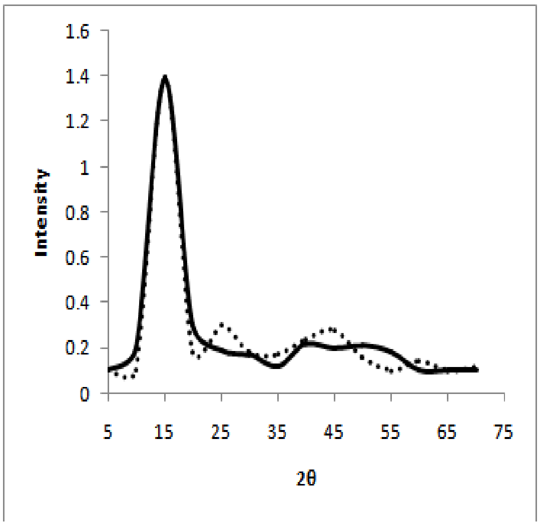


Fig. 9 X-ray diffraction pattern (XRD) of the $Ti0_2$ thin film covered substrate obtained from Hibiscus sabdariffa (—) and Azardirachta indica (……) extracts.