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OPTICAL CHARACTERISTICS AND BANDGAP ANALYSIS OF *Canarium schweinfurthii*, *Telfaira occidentalis* AND Curcuma longa EXTRACT AS NATURAL SENSITIZERS FOR THE PRODUCTION OF DYE-SENSITIZED SOLAR CELLS

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ABSTRACT
In this study the optical properties and bandgap of natural dye extracted from *Canarium schweinfurthii* (ubemgba) leaf, *Telfaira occidentalis* (pumpkin) leaf, and *Curcuma longa* (turmeric) were investigated using solvent extraction method. In particular, the optical properties of the extracts were investigated using UV-Vis absorption spectroscopy. Results show that *Canarium schweinfurthii*, *Telfaira occidentalis*, and *Curcuma longa*have absorption peak of approximately 420nm, 530 nm and 465nm respectively which are within the visible spectrum of white light with band gaps 2.48eV, 3.13eV, and 2.41eV respectively. These optical properties show that the analyzed dyes are transparent in the visible region and have the potentials of dye – sensitized solar cell application.

Keyword: Dye-sensitized solar cell (DSSC), natural dye, optical characteristics, and bandgap

Introduction

Living plants can produce bioelectricity by converting sunlight into electricity through the Photosynthesis cycle (Ryu*et al*, 2010), which occurs when light is absorbed by pigments contained in the thylakoid membrane (Matthew, 2016). Chlorophyll absorbs light in the visible spectrum of solar radiation, and promotes electron transfer. Carotenoids are essential in the photosynthetic cycle, and aid in the transfer of energy to the chlorophyll molecule, supplementing the chlorophyll light collection properties (Hoerner, 2013). Plants and other organisms, such as algae and cyanobacteria, convert solar energy into chemical energy that can then be used as a fuel for later activities. Energy from the sun allows an electron to move quickly across the membrane of the cell. The electron also returns to its point of departure in artificial solar cells and the captured solar energy is lost**.** Photovoltaic power generation using novel, low cost, synthetic systems with the inherently high photon capturing and charge separation efficiency (quantum efficiency) of natural photosystems has been under study. A number of bio-solar cell concepts are being developed, for instance; a protein complex (Photosystem 1 – PS1) derived from spinach chloroplasts is assembled on a peptide membrane to form an electric circuit.

Photovoltaics generally absorb photons from the sun o ver certain minimum photon energy or threshold ener gy referred to as the "energy gap" or bandgap"; hotons with lower energies passing through the absorber, and photons with higher energies absorbed. Absorption takes place in organic molecular structures when photons energy must be higher than that of the threshold. This absorption produces an excited state in the molecular system, generating electrons and holes. Naturally, pigments extracted from leaves, flowers and fruits show different colours and are used as dye – sensitizers in the fabrication of dye-sensitized solar cells.

They are readily available, easy to extract; applied wit hout further purification, andfriendly to the environme nt (Narayan, 2012) compared to rare metal complexes and other organic dyes. In this study, natural dyes have been extracted from *Canariums chweinfurthii* leaf, *Telfairia occidentalis* (pumpkin) leaf and

Curcuma longa (turmeric) and their bandgap and optical characteristics examined as sensitizers for dye – sensitized solar cell application

Materials and Methods

Extraction of chlorophyll from *telfairia occidentalis* (pumpkin leaf) dye and conversion to chlorin e6

Chlorophyll was extracted from *telfairia occidentalis* (Pumpkin) leaf following a modified procedure by Hu *et al.* (2013). A 50g of freshly harvested *telfairia occidentalis* leaf was dipped in boiling distilled water for 5 to 10sec to suppress the formation of Chlorophyllides (any water soluble breakdown product of chlorophyll formed by hydrolysis or emzyme action) and subsequently crushed in a ceramic mortar to disrupt the cells and free the chlorophyll which was then extracted with 200ml of absolute ethanol, and filtered. The filtrate containing dissolved chlorophyll, lipids, and other pigments was further washed with 100ml of toluene, transferred to a 500ml separation flask, and allowed to separate into two layers, an upper toluene layer containing orange coloured carotenoids and lipids discarded and the lower green layer, containing chlorophyll retained. The toluene wash was repeated twice to ensure complete removal of carotenoids. Finally, to the chlorophyll rich ethanol layer was added a 50g of 4A^o zeolite based molecular sieve as a drying agent and allowed to soak for 24hr shielded from sunlight.

Conversion to chlorin e6 sensitizer

Chlorin e6 (Ce6) is a second-generation photosensitizer with antitumor activity when used in conjunction with irradiation. The dried extract of chlorophyll is filtered from the zeolite into a 500ml flask set on a magnetic stirrer. A 20 ml sodium methoxide was then added gently while stirring rapidly. The mixture was allowed to react for 3hrs, and the reaction terminated by the addition of 100ml of 0.1M aqueous HCl causing the chlorin e6 to precipitate out of the solution. The product was then isolated by filtration, washed twice with distilled water, and re-dispersed in toluene (Ansari *et al.*, 2011).

Extraction of natural dye sensitizers from curcuma longaroot (turmeric) and Canariumschweinfurthii (ubemgba) leaf

Curcuma longa root and *Canarium schweinfurthii* leaf were collected; washed in distilled water to remove impurities and contaminants,and then blended separately in a 50ml absolute ethanol as solvent, filtered and stored in a closed dish and covered with aluminum foil to prevent contact with sunlight (Senthil *et al.*, 2014).

Determination of the optical properties and bandgap

The absorbance of the extracts were measured using UV-Vis-NIR absorption spectrum within a range of 300nm to 900nm wavelength. The transmittance (T) is related to absorption (A) by the expression (Filip *et al.*, 2012):

$$A = Log\left(\frac{100}{[\%\,T]}\right) \quad (1)$$

$$= 2 - \log(\%\,T) \quad (2)$$

Where %T is the percentage of light transmitted

The absorption coefficient $\boldsymbol{\alpha}$ determines the distance light of a particular wavelength can penetrate a material before it is absorbed. The absorption coefficient depends on the material and the wavelength of the absorbed light and can be compiled using the equation following Al-ofin *et al.* (2012), thus:

$$\alpha = \frac{1}{d} Ln\left[\frac{1}{T}\right] \quad (3)$$

where d is thickness of the path length or thin film through which the light passes in the liquid sample

The absorption coefficient, α, is related to the extinction coefficient, k, by the expression (Nasir *et al.*, 2013)

$$\alpha = 4\pi k/\lambda \quad (4)$$

Where k is the extinction coefficient and λ the wavelength of the radiation.

The optical energy band gap (E_g) was estimated using the following expression (Yousaf and Abass, 2013)

$$\alpha h v = \beta\left(h v - E_g\right)^{1/2} \quad (5)$$

Where hv is the photon energy, E_g is the optical band-gap,and β is a constant that depends on the properties of the material. E_g values is determined by extrapolating the linear portion of the plots of $(\alpha hv)^2$ versus *hv*.

Results and Discussion

The optical characteristics of the dye – sensitizers are presented from Figures 1 through Figures 4.

Figure 1 through Figure 3 presents the absorption, transmission and reflectance spectra of *Canarium schweinfurthii*,*Telfairia occidentalis*, and *Curcuma longa* extracts. Figure 1 shows that the absorption spectrum of *Canarium schweinfurthii* extract has wide absorption of 300nm to 650nm wavelength. The absorption spectrum shows that maximum absorption up to 420nm wavelength *Telfairia occidentalis* extract has absorption range from 300nm to 550nm wavelength. The absorption spectrum shows maximum absorption of up to 530nm wavelength while that of *Curcuma longa* extracts ranges from 300nm to 580nm with maximum absorption of up to 465nm wavelength. The 530nm and 465nm recorded by *Telfairia occidentalis*, and *Curcuma longa* extracts correspond to green and blue light region. This is due to the chlorophyll and carotenoid pigments present in *Telfairia occidentalis*, and *Curcuma longa* respectively. Matthew (2016) noted that chlorophylls absorb light energy in the red and blue part of the visible spectrum, whereas carotenoids only absorb light in the blue part of the spectrum. Absorption decreases with higher wavelength. Also, it was observed that almost complete visible region of light is covered. This shows that the dyes can be used as an absorber layer for solar cells. Figure 2 shows that the transmittance of *Canarium schweinfurthii* extract is approximately 30% at 680nm wavelength with approximately 24% reflectance at 690nm wavelength (Figure 3). *Telfairia occidentalis*, and *Curcuma longa* extracts have approximately 100% transmittance at 530nm and 680nm wavelength respectively, hence, approximately 0% reflectance at 680nm (Figure 3). The absorption and extinction coefficients were computed and plotted in Figures 4 and 5 respectively. The absorption and extinction coefficients of the dyes show wide band of absorption from 300nm to 560nm with maximum absorption and extinction coefficients in the range of 350nm to 500nm for *Canarium schweinfurthii*, and *Curcuma longa* extracts. The extract of *Telfairia occidentalis* has maximum absorption and extinction coefficients in the range of 500nm to 550nm. This implies that the incident light of these ranges are absorbed faster and completely. Above 560nm, both absorption and extinction coefficients are almost zero indicating that the dyes absorb less above 560nm wavelength. This shows that the selected dye can be used as absorber layer in photovoltaic cells.

Figure 6 shows the relationship between photon energy and wavelength. The three dyes investigated gave similar pattern. Oviri and Ekpunobi (2013) made similar observation in their study and showed that as the photon energy decreases, the wavelength increases from the ultraviolet region to the infrared region.

Bandgap plot of the dyes under investigation are presented in Figure7. The plots show that the bandgap of *Canarium schweinfurthii*, *Telfairia occidentalis*, and *Curcuma longa* are 2.48eV, 3.13eV, and 2.41eV respectively. Generally, the energy band gap (E_g) is due to quantum size effect, and carrier concentration (Sanusi, *et al.*, 2014; Al-ofin *et al.*, 2012)

Conclusion

The optical properties and bandgap of natural dye extracted from *Canarium schweinfurthii* (ubemgba) leaf, *Telfaira occidentalis* (pumpkin) leaf, and *Curcuma longa* (turmeric) was investigated. Solvent extraction method adopted by Diah *et al.* (2014) was used in the extraction of the dye. The optical properties of the extracts were investigated using UV-Vis absorption spectroscopy. It was found that *Canarium schweinfurthii, Telfaira occidentalis,* and *Curcuma longa* had an absorption peak of approximately 420nm, 530 nm and 465nm respectively which were within the visible spectrum of white light with band gaps of 2.48eV, 3.13eV, and 2.41eV respectively. These optical properties clearly show that the analyzed dyes are completely transparent to the visible region and above wavelength region, indicating their potentials in dye – sensitized solar cell application.

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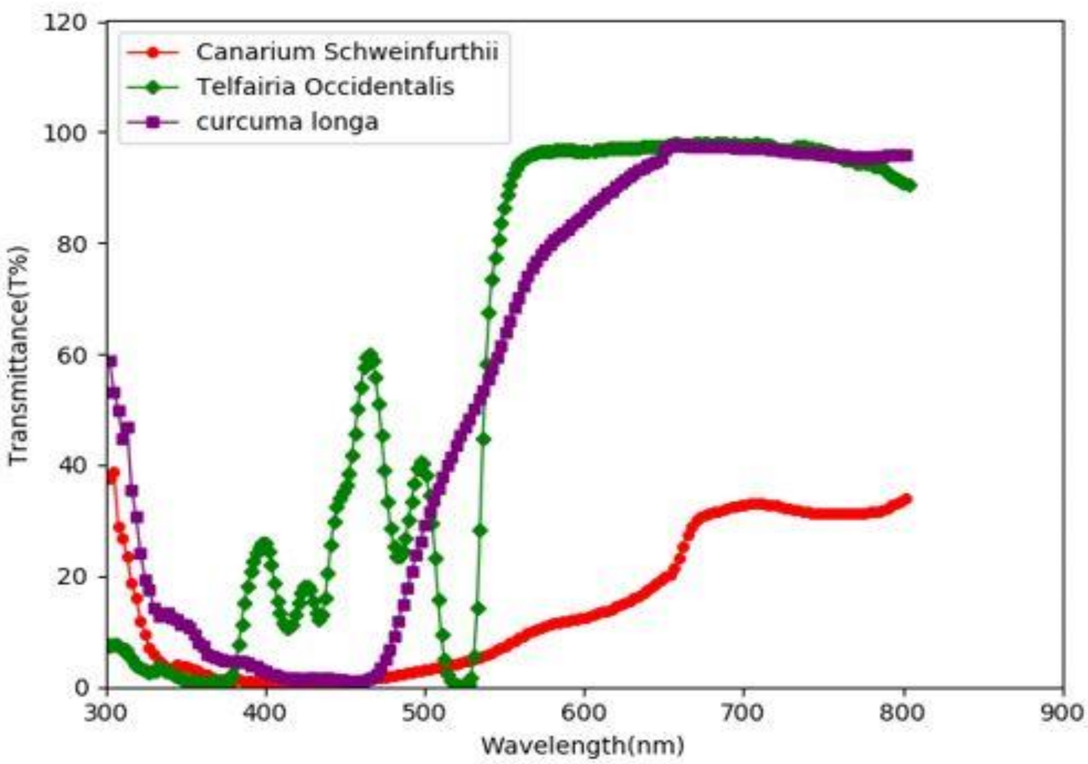


ig.1: Absorbance spectra for *Canarium schweinfurthii* ,*Telfairia occidentalis* (Pumpkin leaf) and *Curcuma longa*

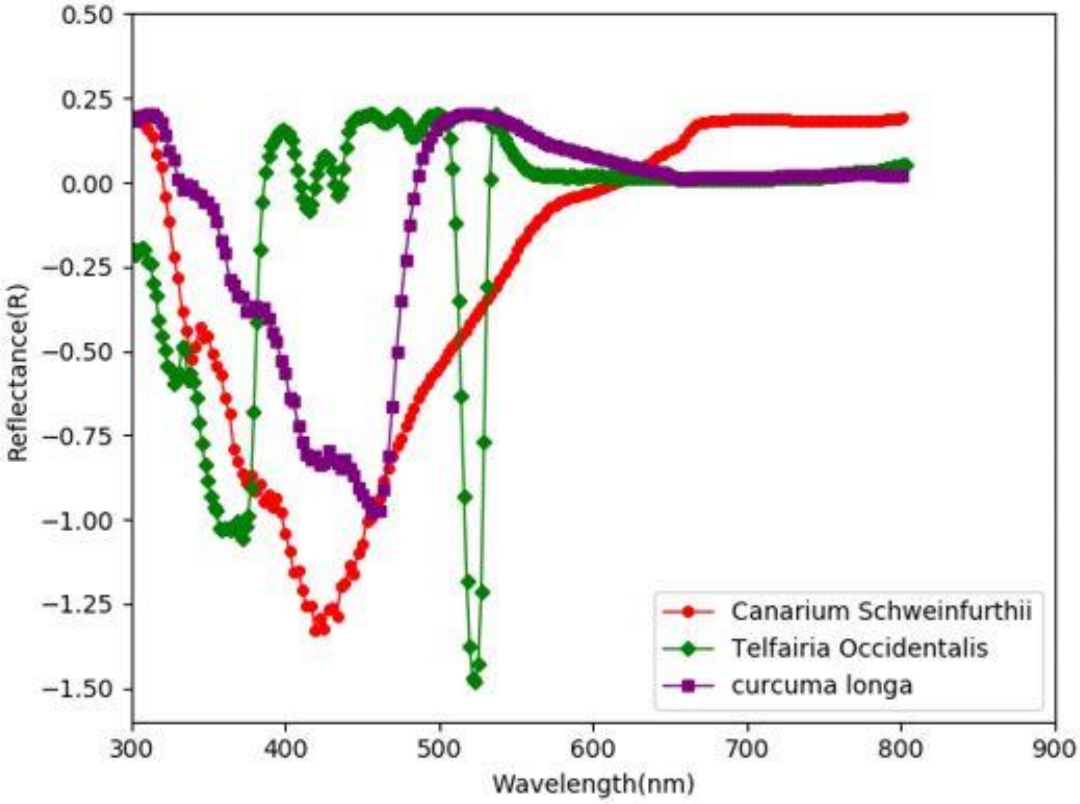


Fig.2: Transmittance spectra for *Canarium schweinfurthii, Telfairia occidentalis (Pumpkin leaf) and Curcuma longa*

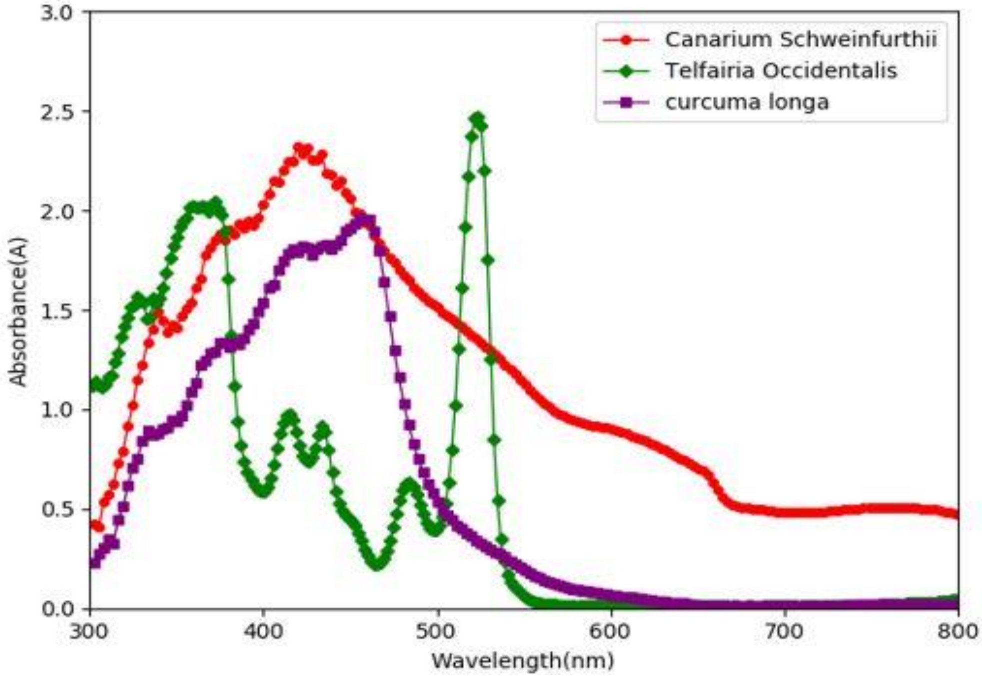


Fig.3: Reflectance spectra for *Canarium schweinfurthii, Telfairia occidentalis* (Pumpkin leaf) and *Curcuma longa*

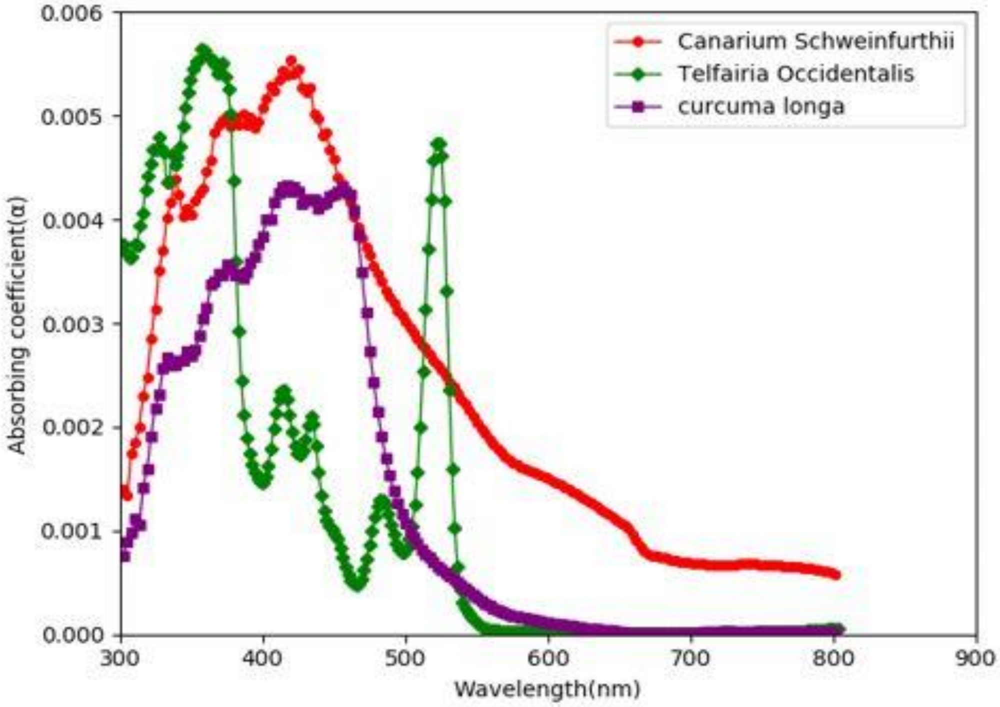


Fig.4: Absorption coefficient spectra for *Canarium schweinfurthii* ,*Telfairia occidentalis* (Pumpkin leaf) and *Curcuma longa*

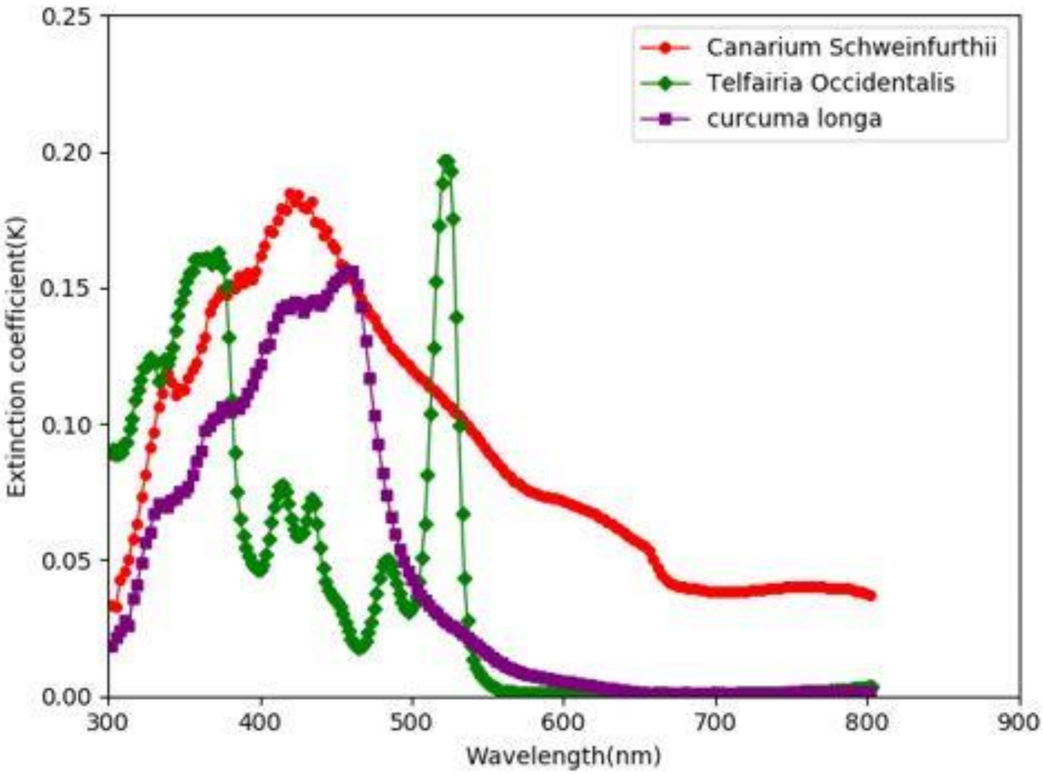


Fig.5: Extinction coefficient spectra for *Canarium schweinfurthii*, *Telfairia occidentalis* (Pumpkin leaf) and *Curcuma longa*

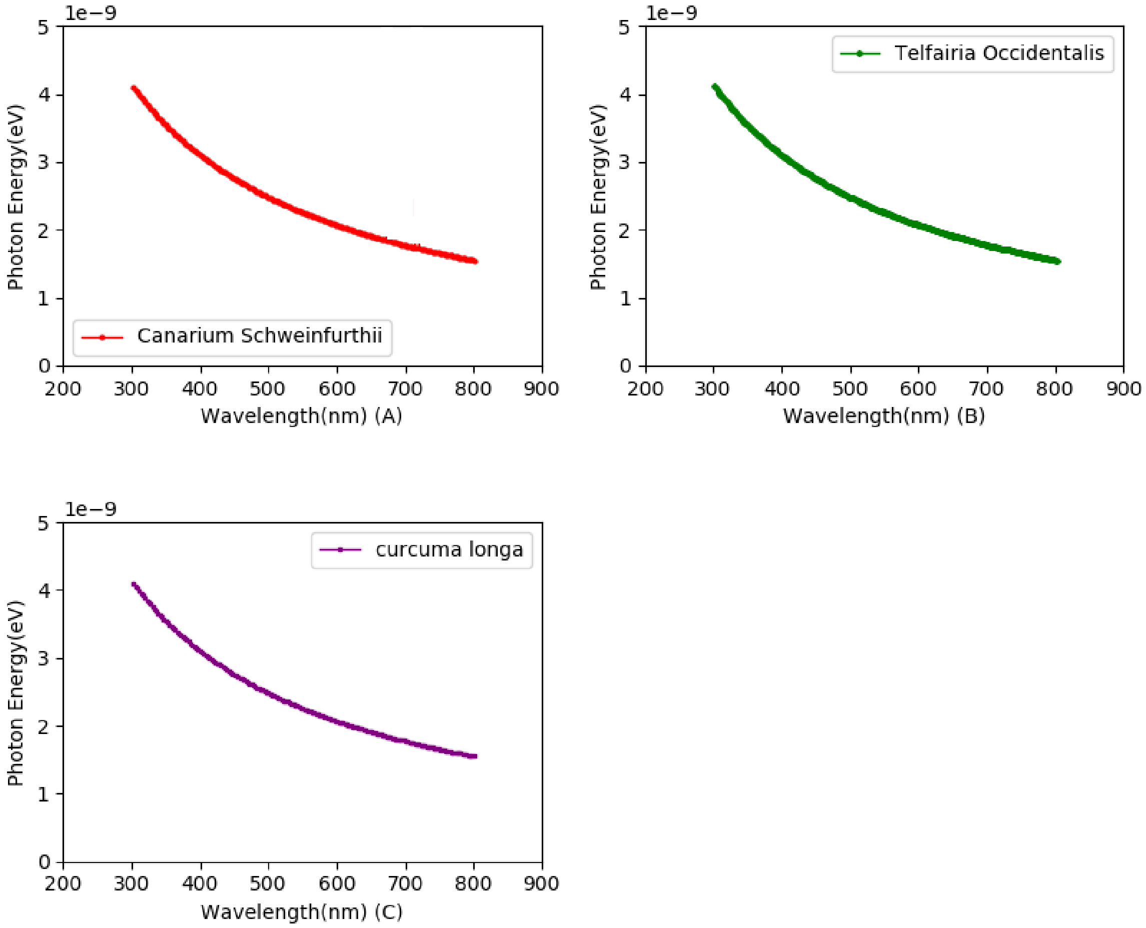
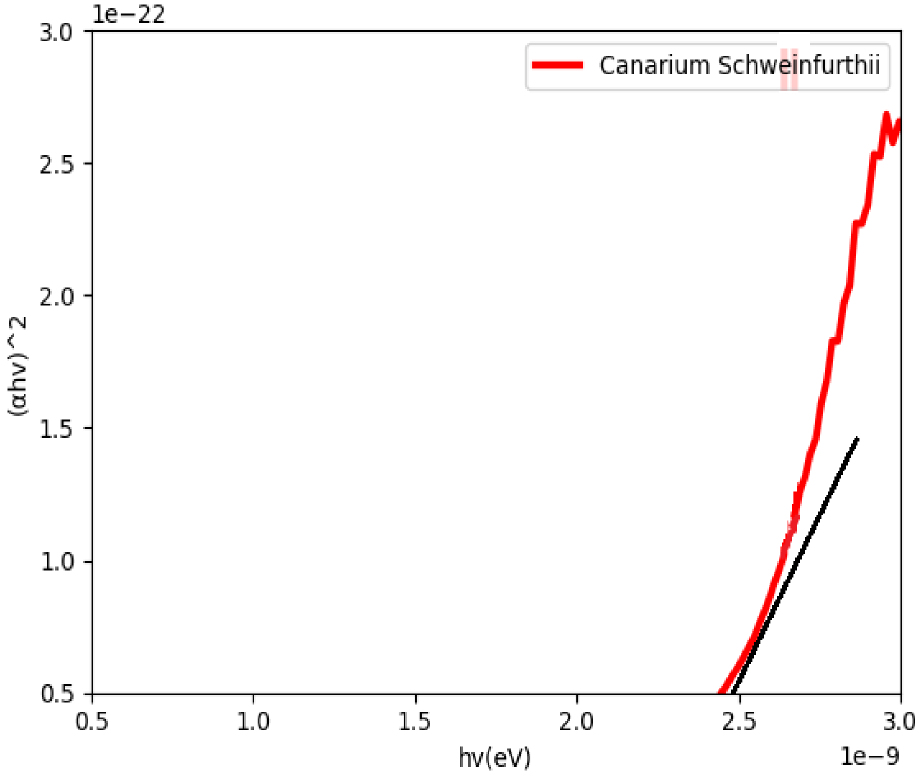
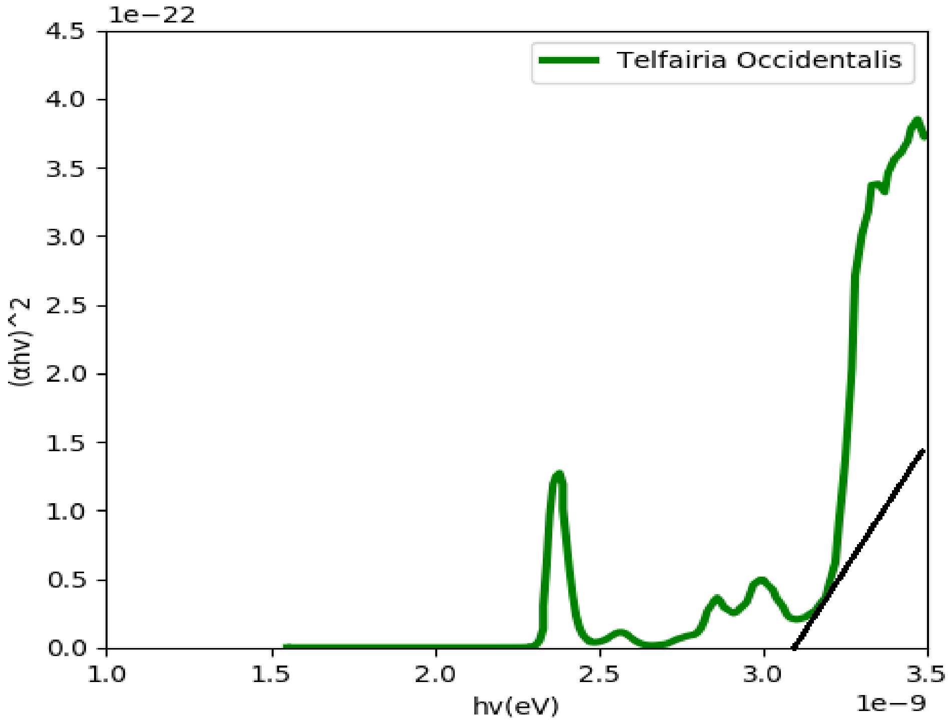


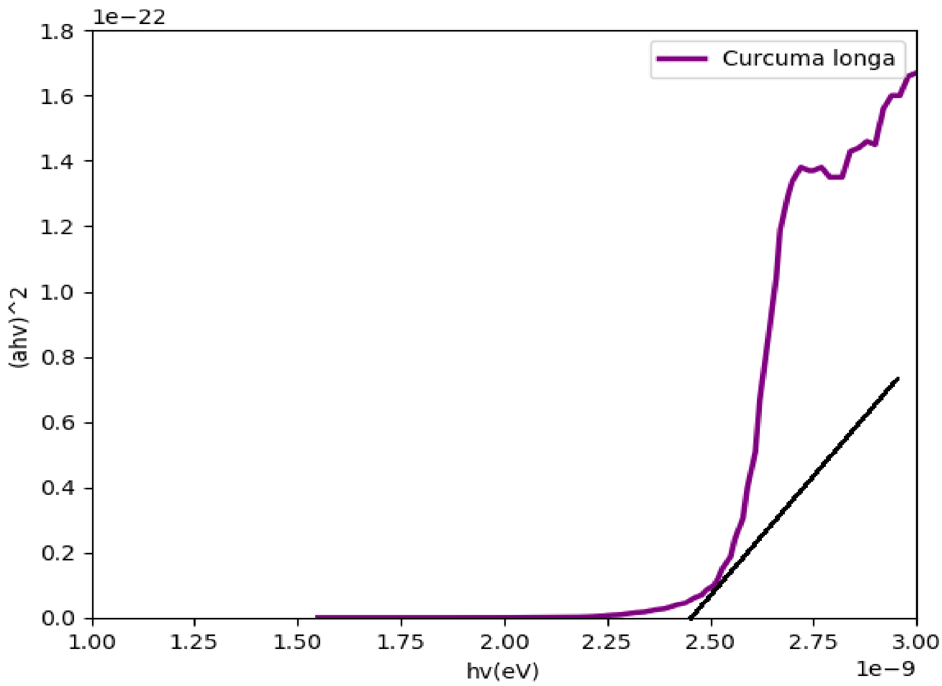
Fig.6: Graph of photon energy against wavelength for the three dye samples



(a)



(b)



(c)

Fig.7: Bandgap of(a) *Canarium schweinfurthii (b) Telfairia occidentalis(c)Curcuma longa*