CONSTRUCTION OF A DYE-SENSITIZED PHOTOELECTROCHEMICAL SOLAR CELL USING PLUMS PIGMENT EXTRACT

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Abstract

Plums (*Prunus Salicina*) are darkly colored fruits which are known to contain anthocyanin pigments. During photosynthesis, anthocyanins are what protects the fruits from UV light and help attract pollinators to them such as bees. Anthocyanins were used to construct dye-sensitized photoelectrochemical solar cells since they can bind titanium dioxide to the hydroxide groups in their chemical structure. The process for extraction of the pigments included soaking the peels of the plums in acidified ethanol solution. The absorbance spectrum was obtained with a UV-VIS spectrophotometer which showed a peak at 530 nanometers. The plums' pigment extract will be used to modify the titanium dioxide in dye-sensitized solar cells which will be further characterized measuring photocurrents with and without irradiation.

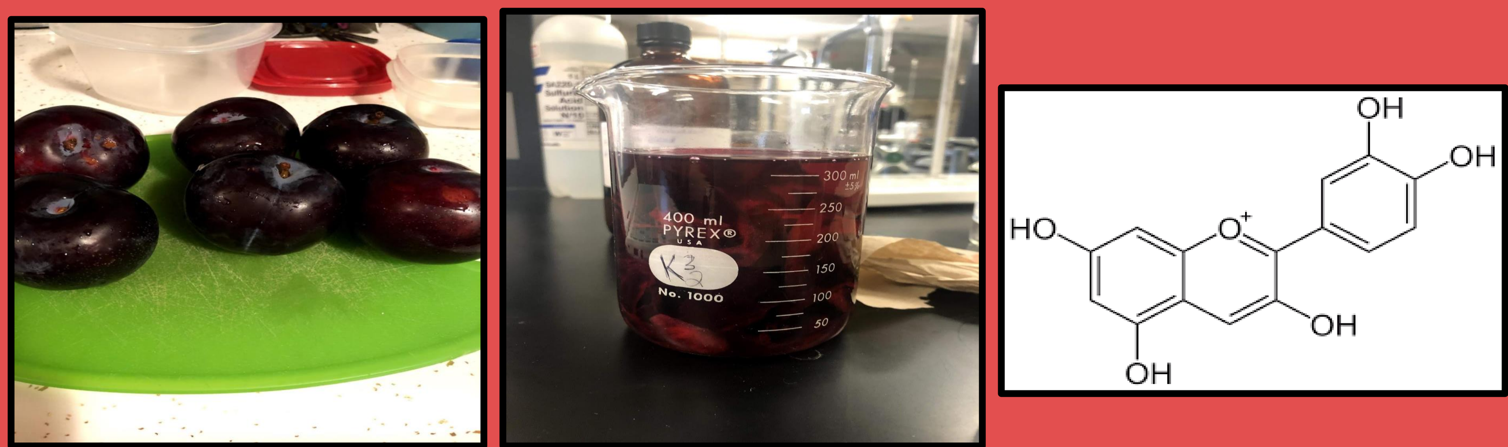

Figure 1. Picture of the purple plums used in the experiment (Left). Picture of final plum solution after the extraction process was completed (Center). Structure of anthocyanin (Right)).

Introduction

A class of flavonoids known as anthocyanins are responsible for the red and purple colors of many fruits and flowers.[1] Anthocyanins are known to be powerful antioxidants that help protect plants from UV damage.[2] Natural dyes, such as chlorophyll derivatives, have previously been used to sensitize TiO_2 nanocrystalline solar cells, achieving efficiencies of 2.6% and 9.4 mA/cm^2, but these dyes still require involved pigment purification and the coadsorption of other compounds on the TiO_2 surface.[3] In acidic solution, cyanin appears red and has a strong absorption band at ~520nm.[3] This visible absorption band is pH and solvent sensitive, causing the dye to appear red (flavylium form) in acidic solution and purple (quinonoidal form) as pH increases, and it is deprotonated.[3] The maximum absorption at 520 to 540 nm in the visible region is the most common wavelength used in the spectrophotometric measurement of anthocyanins.[4]

Solar-powered windows, generate electricity from sunlight, represent an emerging environmental technology that may be able to satisfy the entire energy demand of buildings in future cities.[5] One of the strongest contenders for such a "smart window" technology is the dye-sensitized solar cell (DSC).[5] DSCs are also very cost-effective to the extent that their price-to-performance ratio, which governs the economics of solar cells, exceeds "grid parity" status, i.e., their price-to-performance ratio exceeds that of fossil fuels, which renders them competitive with traditional energy technologies.[5] DSCs comprise four key device components: a chemical dye, a working electrode, a counter electrode, and an electrolyte.[5] The use of organic dyes in DSC devices has gained increasing popularity on account of their low cost and ease of production.[5] Moreover, owing to their sensitivity to different solvents, the optical absorption band of many organic dyes can be tuned via solvatochromism, i.e., the spectral shift of absorption bands upon using different solvents.[5]

Results

The extraction of the plum pigment consisted of soaking the plum skins in an acidic solution for thirty minutes then transferring the solution to a new container as shown in Figure 1. The measured absorbance of the plum solution diluted thirty times showed an absorbance peak in the range of 500 to 540 nanometers is shown in Figure 2 and in Figure 3. The maximum absorption at 520 to 540 nm in the visible region is the most common wavelength used in the spectrophotometric measurement of anthocyanins.[4] The measured fluorescence of the plum solution diluted thirty times was excited at 530nm and used a range of 600 to 800nm detecting a broad emission between 650 and 700 nm as shown in Figure 4. A peak was also observed using a portable fluorimeter and is shown in Figure 5. Another fluorescence spectra will be repeated in the future for a longer amount of time to check for all possible peaks.

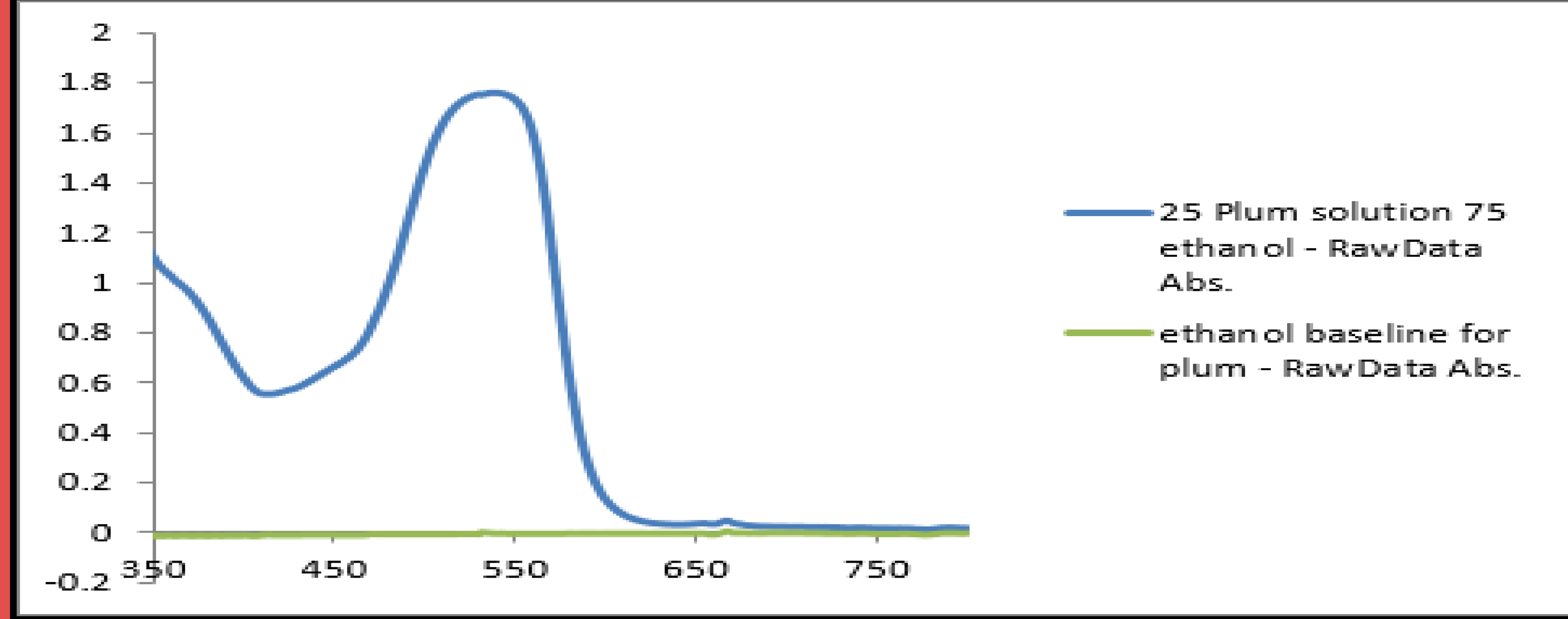

Figure 2. Absorbance spectra obtained from Shimadzu UV-VIS Spectrophotometer. The absorbance spectra indicated a peak around 530 nm for the plum solution (blue). The ethanol baseline (green) for the spectra is also shown for comparison.

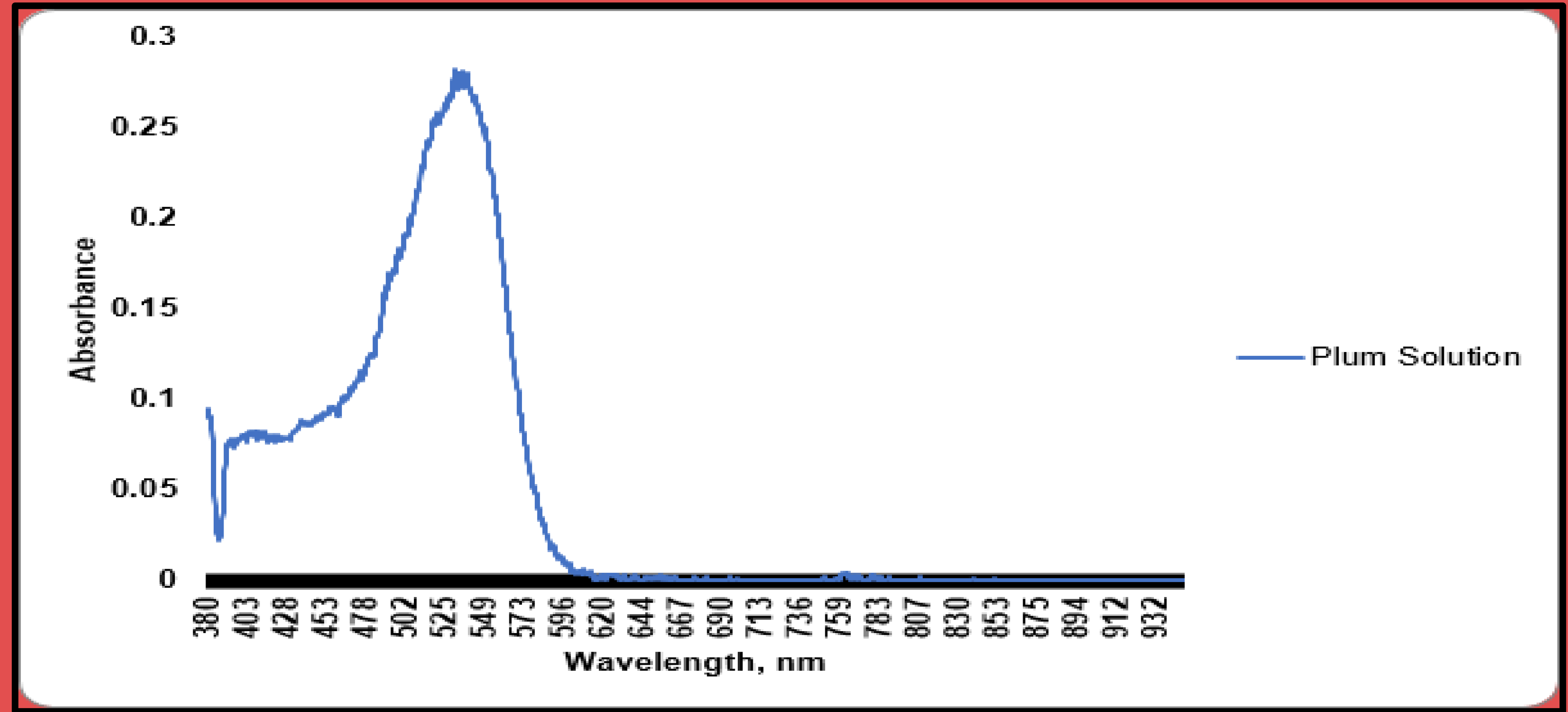

Figure 3. Absorbance spectra obtained from a portable spectrophotometer. The absorbance spectra indicated a peak around 535 nm for the plum solution (blue).

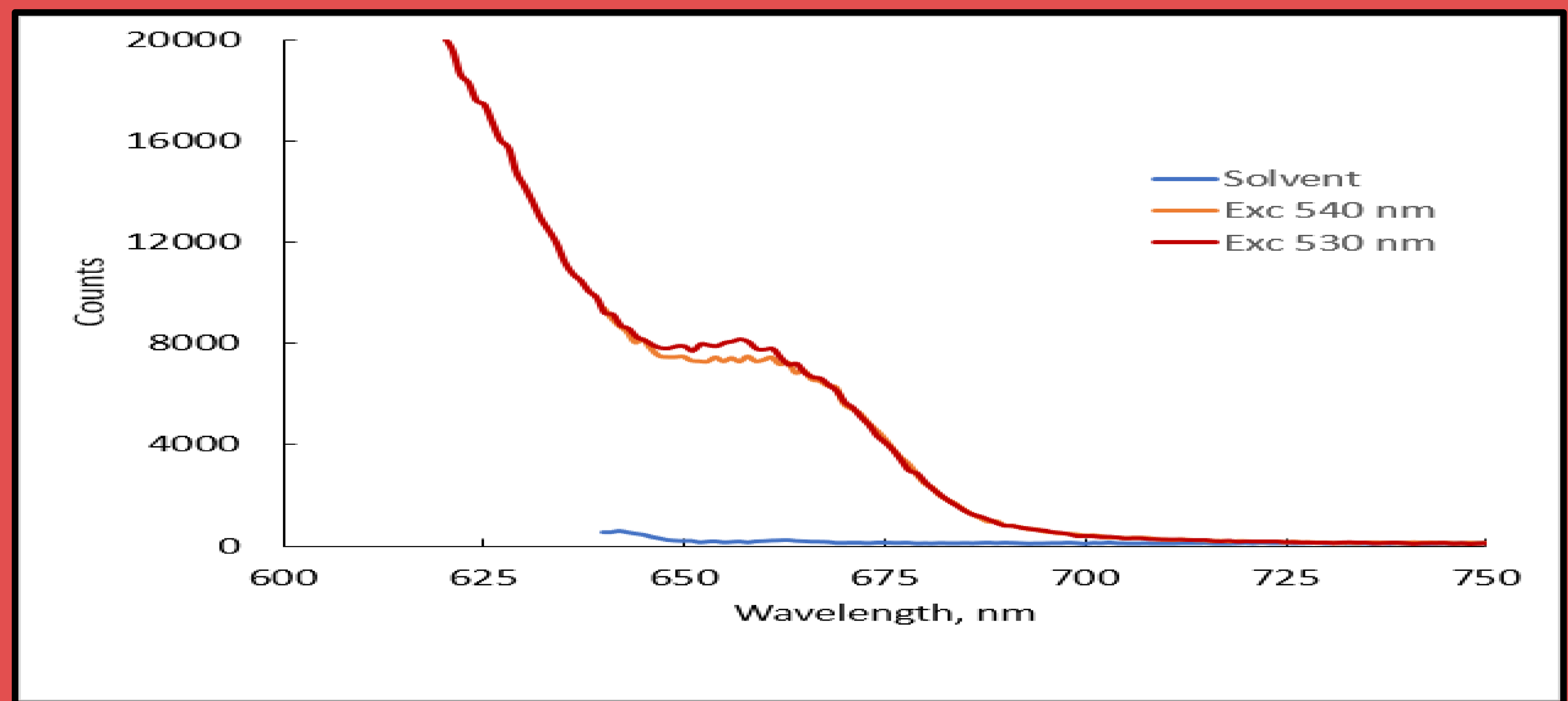

Figure 4. A fluorescence spectrum obtained from a fluorometer. The solvent (blue) was excited at 540 (orange) and 530 (red) nm and included a range of 600 to 800 nm.

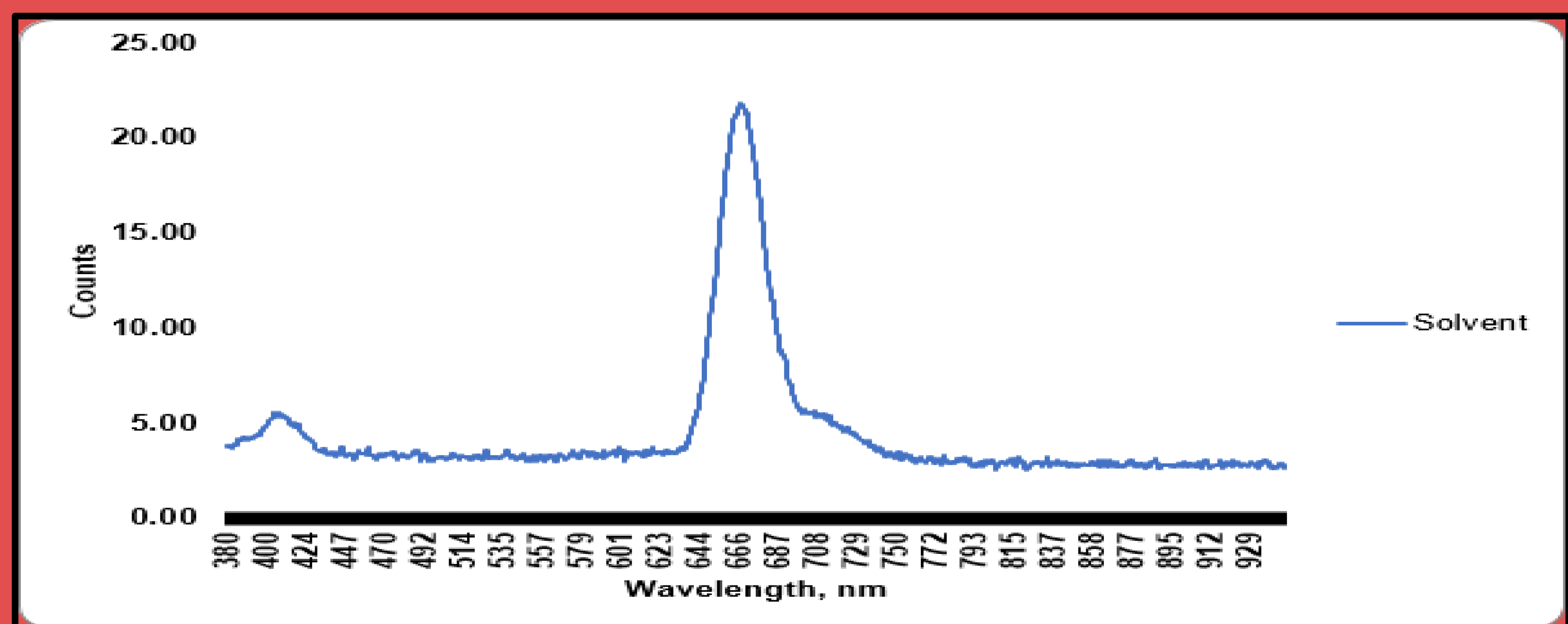

Figure 5. A fluorescence spectrum obtained from a portable fluorometer. The solvent (blue) included a range of 370 to 950 nm and an emission peak around ~666nm.

Experimental

Dye Preparation - Purchased six purple plums from Publix supermarket. Rinsed each plum with water and dried with a paper towel. Peeled each plum with a potato peeler, placed the peels in a tuba ware container. Weighed an empty 400mL beaker on an analytical balance. Placed the plum skins inside the clean 400mL beaker. The plum peels weighed 64.8752 grams. Using a 50mL graduated cylinder, poured 250 mL of ethanol anhydrous into the 400mL beaker of plum skins. Added 16 milliliters of 2M HCl solution to the plum skins and let the solution soak for thirty minutes. Occasionally stirring the solution with a stirring rod. The plum skins were large enough that the solution did not need to be filtered since the skins remained at the bottom when being transferred to another container. The final color of the solution was a dark purple reddish color.

Absorbance Procedure - Placed ethanol anhydrous into the cuvett to be measured as a blank during the absorbance spectra using a spectrophotometer. Used 2900 microliters of ethanol, and 100 microliters of the plum solution so that it would be thirty times diluted. Placed the diluted plum solution into the cuvett and began the absorbance spectra. The recorded results and absorbance graph are in the results section in figure 2and figure 3.

Fluorescence Procedure- Diluted the plum solution with ethanol using a pipet. Measured 2900 microliters of ethanol, and 100 microliters of the plum solution so it would be thirty times diluted. Excited the solution at 530 nm to obtain a fluorescence spectra using a fluorometer and used a range of 600 to 800nm. The results are shown in figure 4 and figure 5.

Solar Cell Procedure - Due to the circumstances of the virus I was unable to finish the construction of my dye sensitized solar cell. First, the chemical dye absorbs light from the sun.[5] Then, in its photoexcited state, the dye molecule injects an electron into the semiconductor electrode (usually TiO_2 nanoparticles) onto which it is absorbed.[5] This generates a potential difference with respect to this working electrode and a counter electrode (a transparent conducting oxide, usually fluorine-doped tin oxide, FTO); as such, this injected electron is transported to the counter electrode, i.e., initiating the electrical current in the solar cell.[5] An electrolyte is contained between the electrodes and acts as a redox couple, accommodating the electron from the counter electrode and passing it back to the dye to regenerate its ground state, thus completing the electrical circuit.[5]

Conclusions

The purpose of the experiment was to extract the anthocyanin pigment from the skins of plums to create a dye-sensitized photoelectrochemical solar cell. The extraction procedure included soaking the skins of the plums in ethanol and 2M hydrochloric acid for thirty minutes then transferred the solution to another container. The solution was diluted thirty times since it was originally so highly concentrated with hydrochloric acid. The plum solution was used in a spectrophotometer to measure the absorbance of the anthocyanin. And the plum solution was used in an emission and excitation spectra to measure the fluorescence that would be emitted from the pigment. The measured absorbance of the plum solution showed an absorbance peak in figure 2 and figure 3 around ~530 to 535 nm. In figure 4 the measured fluorescence of the plum solution was excited at 530nm and ran a range of 600 to 800nm. In figure 5 the measured fluorescence showed a peak around ~666 nm and ran a range of 370 to 950nm. While the absorbance spectra match expected values for anthocyanins further measurements using fluorescence are needed to confirm the presence of anthocyanins. The next step for this experiment will be to create a dye-sensitized photoelectrochemical solar cell using the pigment that was extracted.

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