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Research Article

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Extraction and Characterization of dye from Gautan Kura (*Solanum incanum*) from Gaanda, Adamawa State Nigeria

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Abstract Gautan Kura (*Solanum incanum*) plant shows good quality for sensitization of photoelectrochemical solar cell. FTIR analysis of the plant extract reveals functional groups of alcohols, ketones, aldehydes and carboxylic acids.

Keywords Extraction, Characterization, Dye, Gautan Kura, *Solanum incanum*

Introduction

The use of natural dyes in solar cells offers promising prospects for the advancement of this technology, because fabrication of cost effective solar cells is a scientific challenge. The use of natural pigments cut down the cost of chemical synthesis and high cost of rare metals need for metal organic dye sensitizers. Therefore lot of interest has been drawn on natural dyes extracted from plant materials. Several natural pigments have been utilized as sensitizers in photovoltaic cells due to their capability of injecting electron from excited pigments to the conduction band of the semiconductor material. Most natural pigments that can be utilized in dye sensitized solar cells undergo rapid photo degradation. Cyanidin is an organic dye of the flavonoid class found in leaves and fruits of plants and responsible for the colors of various vegetable tissues, which have been studied as a sensitizer in solar cells that found to be photo stable [1]. Natural pigments have also demonstrated a capacity of functioning as the pigment in DSSCs [2].

Dye-sensitized nanocrystalline solar cell is a nonconventional solar electric technology that gained the attention of the photovoltaic community. Its foundations are in photochemistry rather than in solid state physics, the discipline underlying today's conventional solar cells. Photovoltaic devices are based on the concept of charge separation at an interface of two materials of different conduction mechanism [3]. The dominance of photovoltaic field by inorganic solid state junction devices is now being challenged by the emergence of a third generation of cells which is based on nanocrystalline conducting polymer films [4]. This offers the prospective of very low cost fabrication and presents attractive features that facilitate market entry. It can now be possible to move away from the classical solid-state junction devices by replacing the contacting phase to the semiconductor by an electrolyte, liquid, gel or solid thereby forming a photochemical cell. A progress has recently being realized in the fabrication and characterization of nanocrystalline materials and this has opened up vast new opportunities for this systems.

The dye-sensitized nanocrystalline solar cell therefore realizes the optimal absorption and charge separation processes by association of a sensitizer as light absorbing material with a wide band gap semiconductor of nanocrystalline morphology. To date this field has been dominated by solid-state junction devices usually made of silicon, and profiting from the experience and material availability resulting from the semiconductor industry

[5]. Since the development of dye-sensitized solar cells, these have attracted considerable attention due to their environmental friendliness and low cost of production. In dye sensitized solar cells, the dye as a sensitizer plays a key role in absorbing sunlight and transforming solar energy into electric energy. Numerous metal complexes and organic dyes have been synthesized and utilized as sensitizers. By far, the highest efficiency of dye sensitized solar cells sensitized by Ruthenium containing compounds adsorbed on nanocrystalline TiO_2 reached 11–12% [6]. Although such dye sensitized solar cells have provided a relatively high efficiency, there are several disadvantages of using noble metals in them since noble metals are considered as resources that are limited in amount, hence their costly production.

On the other hand, organic dyes are not only cheaper but have also been reported to reach efficiency as high as 9.8% [7]. However, organic dyes have often presented problems such as complicated synthetic routes and low yields. Nonetheless, the natural dyes found in flowers, leaves, and fruits can be extracted by simple procedures. Due to their cost efficiency, non-toxicity and complete biodegradation, natural dyes have been a popular subject of research. Thus far, several natural dyes have been utilized as sensitizers in dye sensitized solar cells, such as cyanin, carotene, tannin and chlorophyll [8]. Calogero and Marco [9] reported that a conversion efficiency of 0.66% was obtained using red Sicilian orange juice dye as sensitizer. Wongcharee *et al.* [10] employed rosella as sensitizer in their dye sensitized solar cell, which achieved a conversion efficiency of 0.70%. Furthermore, they carried out structural modification of coumarin and used the coumarin derivation dye as sensitizer in their dye sensitized solar cell, which provided an efficiency of 7.6%. Thus, optimization of the structure of natural dyes to improve efficiency is promising aspect of the development of this type of cells. This piece of work includes an investigation of photosynthetic pigments rather than inorganic complexes.

Fundamentals of the Porous Nanocrystalline Solar Cell

The basis of a solar cell is a semiconductor. Its properties include enabling electron separation and transport, allowing electricity to be yielded from sunlight [11]. The semiconductor is a crystalline substance and all its atomic levels have merged to form two bands, the valence band (VB) and the conduction band (CB). The VB and the CB of the semiconductor crystal are analogues to the molecular concepts of HOMO (highest occupied molecular orbital) and LUMO (lowest unoccupied molecular orbital) [11].

Extraction of Dye

Fresh fruits of the plant *Solanum incanum* were cut using a sharp knife from farmlands around Gaanda Primary School, Gombi Local Government area, Adamawa State of Nigeria where the plant grows in relative abundance. The plant and hence the fruits were identified in the Biological Sciences Department Modibbo Adama University of Technology Yola, Adamawa State.

The fruits were washed with tap water and the bark carefully peeled off and put into a beaker and 99.9% ethanol was added to the beaker. This was all together kept in a water bath maintained at about 70 ^{0}C for five hours. The solid residue was then filtered out using filter paper, funnel and beaker to obtain a clear dye solution as described by Nishantha [1].

Staining the thin film with dye

The dye was coated on the sintered substrate while still warm by slowly immersing it face up into the dye solution extracted from the fruits of *Solanum incanum* into ethanol. This was kept for 48 hours in the dark for proper impregnation. After this period, the substrate was removed, rinsed with pure ethanol and dried with stream of warm air.

Fourier Transform Infrared Measurement

The absorption spectra of the dye were recorded using an FTIR spectrophotometer (Nicolet IR 100). Two drops of dye solution on one of the KBr plates of the spectrophotometer was evenly spread around its top into a thin capillary film by enclosing the second plate on top of it. The plates were gently inserted into the plate holder which was then introduced into the IR spectrophotometer after being screwed tight. The background was collected and then followed by the IR measurement of the sample.

GC-MS analysis

GC-MS analysis of the ethanol extract of *Solanum incanum* was performed using an Agilent Technologies 7890A GC system comprising an Agilent Technologies 7683B Series auto-sampler and a Gas Chromatograph interfaced to a Mass Spectrometer (GC-MS) equipped with Agilent Technologies 5875C inert MSD fused to a capillary column (30 × 0.32 mm ID × 0.25 μmdf). For GC-MS detection, an electron ionization system was operated in electron impact mode with ionization energy of 70 eV. Helium gas (99.999%) was used as a carrier gas at a constant flow rate of 1 mL/min, and an injection volume of 2 μL was employed (a split ratio of 10:1). The injector temperature was maintained at 250 °C, the ion-source temperature was 200 °C, the oven temperature was programmed from 110 °C (isothermal for 2 min), with an increase of 10 °C/min to 200°C, then 5 °C/min to 280 °C, ending with a 9 min isothermal at 280 °C.

Mass spectra were taken at 70 eV; a scan interval of 0.5 s and fragments from 45 to 450 Da. The solvent delay was 0 to 2 min, and the total GC/MS running time was 36 min. The relative percentage amount of each component was calculated by comparing its average peak area to the total areas. The software adopted to handle mass spectra and chromatograms was a Turbo-Mass ver-5.2.

GC-MS Analysis

Gas chromatography-mass spectrocopy chromatogram analysis of the ethanolic extract of *Solanum incanum* showed peaks which indicate the presence of phytochemical constituents. On comparison of the mass spectra of the constituents with the NIST library, the phyto-compounds were characterized and identified (Table 1). The mass spectra of all the phytochemicals identified in the whole plant ethanolic extract of *Solanum incanum* were presented in Figure 2 of the five compounds identified, the most prevailing compounds were ethanol, a methanenitroso- compound (1.92%) and 2,2-Dichloroethyl methyl ether and 2-Propanol, 1-chloro- , each having composition of 1.59%. The high percentage of ethanol was attributed to the fact that extraction of the pigment was done in that medium. The chromatogram therefore may suggest the presence of a flavonoid structure from the dye molecule.

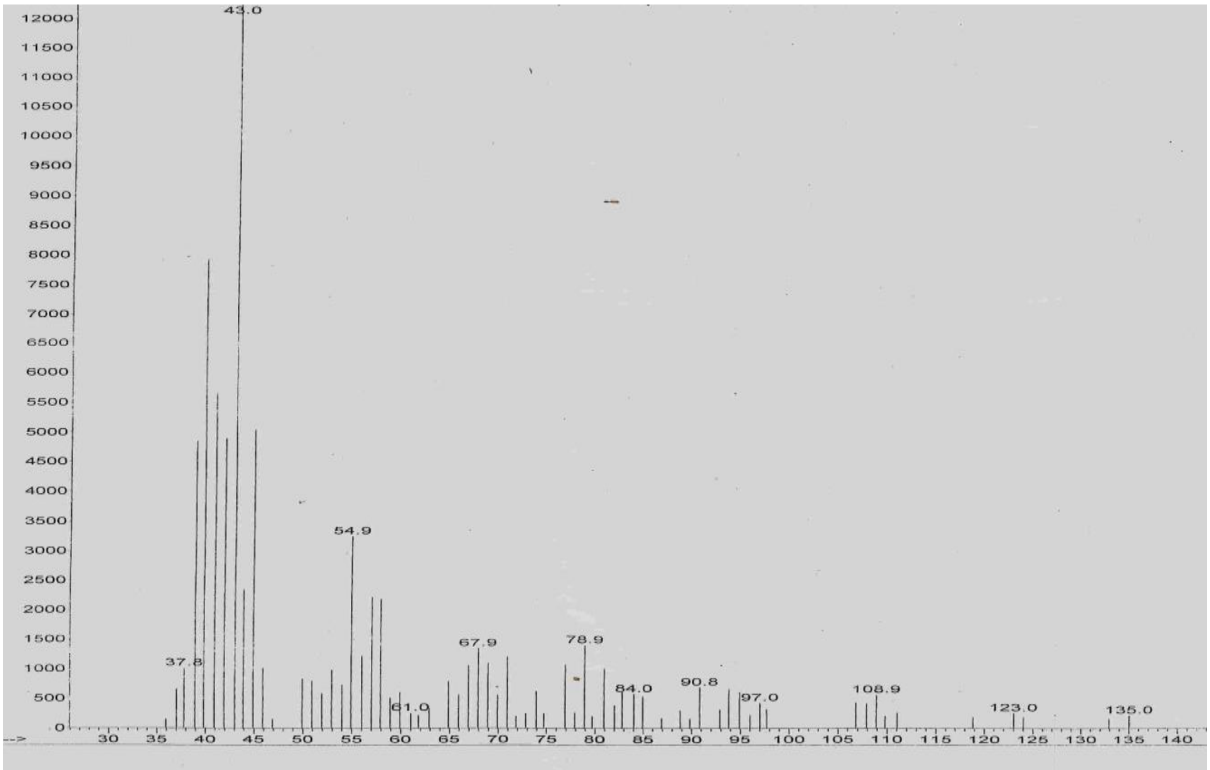

Figure 1: GC-MS chromatogram of Solanum incanum ethanolic extracts

Table 1: Phytocomponents identified in the ethanolic extract of *Solanum incanum* by GC-MS

No.	RT	Name of compound	Molecular weight	Peak Area %
1	1.23	Methane, nitroso-	45	1.92
2	1.34	2,2-Dichloroethyl methyl ether	128	1.59
3	1.34	2-Propanol, 1-chloro-	94	1.59
4	4.12	Pyridine	79	0.24
5	3.27	Ethanol	46	94.66

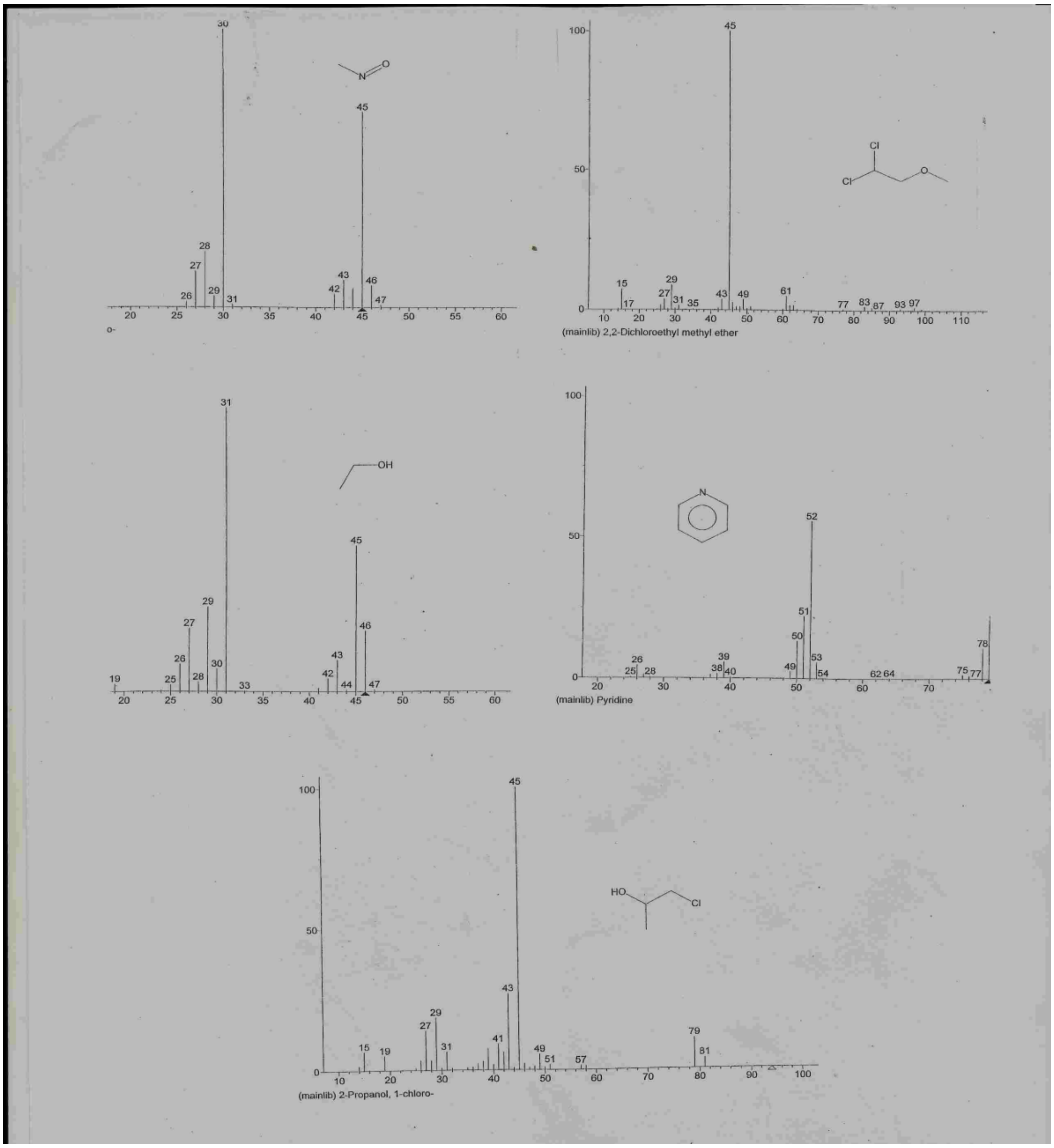

Figure 2: Mass spectrum and structure of phytocomponents identified by GC-MS in the ethanolic extracts of Solanum incanum

Conclusion

The natural dye extracted from the fruits of *Solanum incanum* plant shows good quality for sensitization of photoelectrochemical solar cell. FTIR analysis of the plant extract reveals functional groups of alcohols, ketones, aldehydes and carboxylic acids. It gives the dye a tendency to be adhered to the porous TiO_2 semiconductor which facilitates injection of electrons to its conduction band.

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