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Carbon Quantum dot Synthesis from Indigo Plant (*Indigofera tinctoria* L.)

Mohammad Reza Zargaran Khouzani [a*] and Seyed Mohammad Amin Daei Naseri [b]

[a] *Department of Agrotechnology, Faculty of Ecological Plants, Khuzestan University, Bavi, Iran.*
[b] *Department of Applied Chemistry, Faculty of Chemistry, University of Mazandaran, Babolsar, Iran.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

One of the main challenges of making Nano catalysts is choosing and preparing suitable modifiers. The present study reports the synthesis of carbon Nano dots by a low-cost hydrothermal method using *Indigofera tinctoria* leaf extract as a new carbon precursor. The optical properties of CQDs were analyzed by UV-visible spectroscopy and fluorescence studies. Surface morphology, functional groups and crystallization of CQDs were evaluated by HR-TEM, FT-IR and XRD methods, respectively. The spherical appearance of the synthesized CQDs was confirmed by HR-TEM, and the calculated size of the CQDs was 4 nm. XRD and SAED pattern results provide evidence for the amorphous nature of the prepared CQDs. The thermal stability of CQDs was investigated using TGA analysis. The obtained CQDs acted as a green Nano catalyst.

Keywords: Green; synthesis; indigo plant carbon quantum dots.

**Corresponding author: E-mail: mr.zargarankh@gmail.com;*

1. INTRODUCTION

Carbon-based nanomaterial's such as carbon nanotubes [1], graphene oxide [2], fullerenes [3] and carbon quantum dots [3] have played vital roles in science and technology in the past two decades. Meanwhile, carbon quantum dots (CQDs) are fluorescent carbon nanomaterial's that have been at the forefront of recent research [4]. “Carbon quantum dots (CQDs) are nanoparticles with a size of 1–10 nm that were unexpectedly discovered by Anbu et al. During the purification of single-walled carbon nanotubes in 2004” [5]. “The properties of CQDs mainly depend on two factors: first, the choice of carbon source (raw material), and second, the synthesis method. CQDs are popular due to their unique properties, such as high water availability, strong chemical inertness, fluorescence, excellent photo stability, less toxic nature, excellent biocompatibility, environmental friendliness, low cost, and complete flexibility. They are different from other carbon-based nanomaterial's. Surface modification” [6-7]. “CQDs have versatile applications in various fields, such as drug delivery, optoelectronic devices, metal ion sensing, biological imaging, biomolecules, catalysis, solar cells, and oxygen reduction reaction” [8].

“CQDs have been synthesized by various top-down methods. including laser ablation, ultrasonic treatment, electric arc discharge, and electrochemical and chemical oxidation, and bottom-up methods such as hydrothermal carbonization, microwave irradiation, pyrolysis, and plasma treatment” [9]. “Among these synthesis methods, arc discharge and laser ablation processes require very expensive tools, while electrochemical oxidation and chemical oxidation require strong acids. The microwave irradiation method shows a simple way to synthesize CDs in a few minutes. This method can be limited by uncontrolled reaction conditions. The hydrothermal method is simple, rapid and cost-effective, has a simple experimental setup, and is environmentally friendly compared to other synthesis methods. Carbon dots with tunable degrees of carbonization are usually composed of carbon (C), oxygen (O), and hydrogen (H) decorated with different functional groups on their surfaces. The use of cheap and environmentally friendly biomass sources such as Phyllanthus emblica, prickly pear cactus, rice bran, Coccinia indica and sweet potato as carbon precursors for CQD harvesting has attracted much attention due to their green approach” [6]. “Plant extracts containing citric acid, tartaric acid and ascorbic acid act as efficient carbon precursors for the synthesis of highly fluorescent CQDs. The fluorescence properties of CQDs are influenced by the solvents, size, pH, and impurities used during synthesis. Recently, surface functionalization of CQDs was achieved by doping heteroatoms (such as boron, sulfur, nitrogen, and phosphorus). Nitrogen functionalization enhances the optical properties of CQDs compared to smokeless CQDs. At the same time, other important properties of CQDs, such as quantum yield (QY) and fluorescence lifetime are significantly improved by the functionalization approach. In addition, heteroatom doping affects the internal sharing of electrons in the CD and thus can change the band gap energy, leading to an intensification of the CQD fluorescence intensity” [7]. “These functionalized CQDs serve as remarkable fluorescent probes in biological, catalysis, and chemical sensing applications” [10]. “Among carbon materials, CQDs are considered as a new generation material with excellent electron transfer capability, a suitable alternative to other carbon competitors. CQDs offer a high potential to replace traditional semiconductor quantum dots due to their unique luminescence performance, smaller size, good solubility, biocompatibility, increased adsorption capacity of reactive substrates, and low toxicity. Also, these compounds have many applications in the development of biological imaging, medical diagnosis, catalysis, etc. CQDs can be prepared from natural materials such as fresh mint leaves banana peel scraps, etc.” [11].

The indigo plant belongs to the legume family and its main habitat was India. Indigo root and stem have bitter taste and laxative effect. It is expectorant and anti-parasitic and strengthens hair. All parts of this plant reduce inflammation and are used to treat chronic bronchitis, asthma (especially in children), hemorrhoids, insect bites and venomous reptiles. In terms of the chemical compounds in the plant, it is used to treat wounds and skin disorders. The color extracted from this plant is known in ancient civilizations such as Mesopotamia, Egypt, Greece, Rome, England, Central America, Peru, Iran and Africa [12]. This study aims to synthesize green carbon quantum dots from a native plant called indigo with the scientific name *Indigofera Tinctoria* L. It is a medicinal-industrial plant from the legume family that is cultivated in the south of Iran

(Shoushtar) [13]. The components of the indigo plant include: alkaloids, glycosides, flavonoids, tannins and phenolic compounds, amino acids, carbohydrates, mineral compounds, other compounds such as ash, acid-soluble ash, water-soluble ash, etc. Our goal in this research is to prepare quantum dot carbon using natural resources such as indigo plant by hydrothermal method [14].

2. MATERIALS AND METHODS

2.1 Chemicals and Reagents

Indigofera tinctoria leaves were collected in the city of Shoushtar in the province of Khuzestan. All chemicals and reagents were laboratory grade except for additional purification. Double distilled water was used to prepare the solution and for other purposes during the study.

2.2 Preparation of the Extract

Freshly harvested leaves of *Indigofera tinctoria* (50 g) were thoroughly washed with distilled water to remove impurities. The cleaned leaf was ground homogeneously in an electric stirrer by adding 100 ml of bid stilled water. The mixture was continuously heated to 30°C, stirred for 1 h, then filtered, first using Whatman filter paper, then by centrifugation at 10,000 rpm for 15 min. Finally, the supernatant was collected and used as a carbon source for CQD synthesis.

2.3 Synthesis of CQDs

In this study, carbon quantum dots were synthesized by hydrothermal method from indigo as a precursor in deionized water at 200°C for 14 hours. The sample was dried in an oil bath and washed three times with ethanol. Finally, the resulting black powder was dried in a vacuum oven for 6 hours.

Fig. 1. Chemical structure of indigo carmine (indigo blue dye)

Fig. 2. Quantum dot carbon extraction method from indigo plant

3. RESULTS AND DISCUSSION

Fig. 3 presents the FT-IR spectrum of the CQD. The broad peak at 3357 cm^{-1} confirms the stretching vibration of the O-H bond of the acidic and alcoholic functional group. The peak at 2931 cm^{-1} shows the stretching vibration of the C-H bond of SP^3. At 2364cm^{-1} C-H SP^2 stretching vibration of benzene ring of carbon dot structure and at 1591cm-1 N-H bending vibration is confirmed. The peak at 1416cm^{-1} O-H bending vibration is related to acidic and alcoholic functional groups. The two peaks at 1650cm^{-1} and 1078cm^{-1} show the stretching vibration of C=C and C-O, respectively. The peaks in the area of 672-751cm^{-1} show the bending vibration of C=C.

Fig. 4 shows the uv-vis analysis of the sample in the range of 190-400nm in water solution. The peak in the region of 210 nm represents the electron transfer π to π* of C=C double bonds and the peak at 250 nm represents the n to π* electron transfer caused by the pair of non-bonding electrons of nitrogen or oxygen.

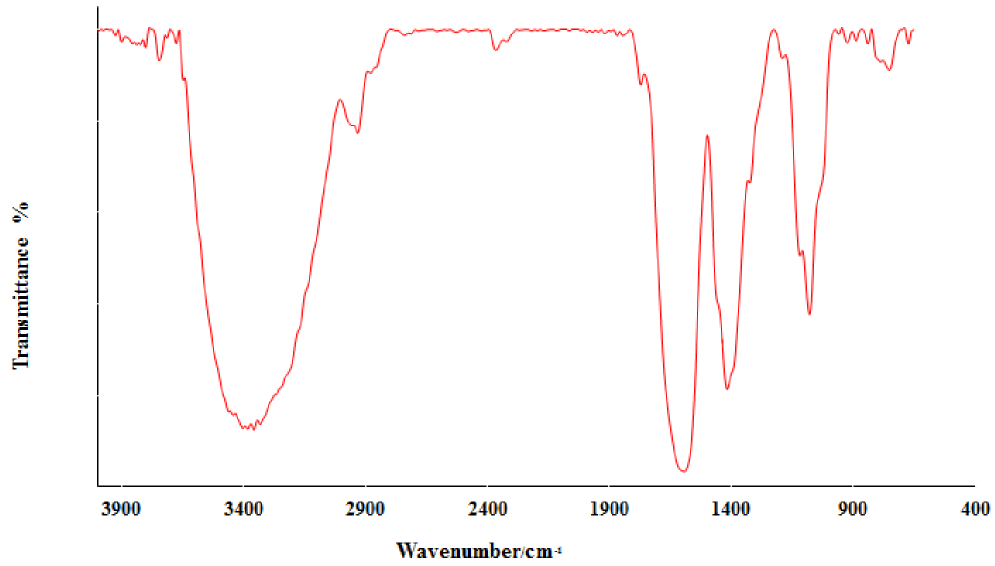

Fig. 3. FT-IR of prepared sample

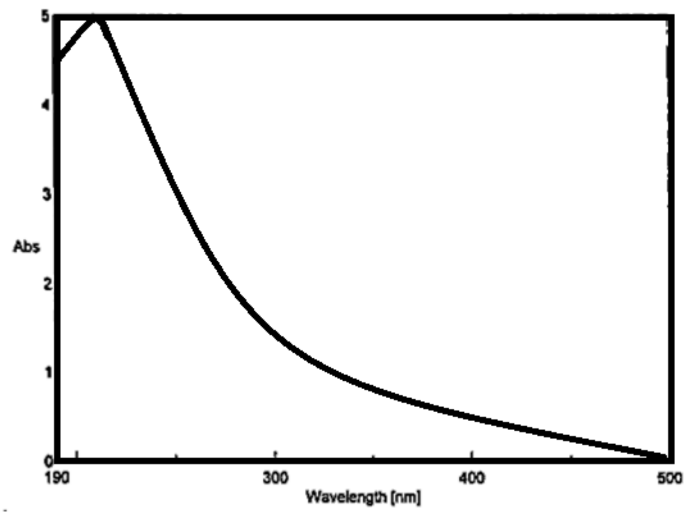

Fig. 4. Uv-Vis of sample

Fig. 5. Extract extracted from the indigo plant

4. CONCLUSION

Considering the importance of using carbon materials to modify the electrode surface and the features mentioned for carbon quantum dot, we prepared carbon quantum dot using indigo plant and with a hydrothermal method. Carbon quantum dot prepared by methods such as IR and UV. etc. We identified and checked. The synthesized material can be used to modify the electrode surface in sensing applications, corrosion, etc. This work can be a model for preparing carbon quantum dots from other natural sources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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