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Original Research Article

Evaluation of Antioxidant Activity of Zinc-Doped Carbon Quantum Dots

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Abstract: In this study, zinc-doped carbon quantum dots (Zn-CQDs) were synthesized using a hydrothermal method. The quantum dots were characterized using FTIR, and TEM. FTIR confirmed the presence of hydroxyl, carboxyl, amine groups.TEM analysis revealed spherical morphology with sizes less than 5nm. The biological activity of the CQDs were evaluated through total antioxidant capacity assay. Zn-CQDs showed a strong antioxidant capacity equivalent to 148.27 µg/mg ascorbic acid. These findings suggest that Zn-CQDs hold promise for future biomedical applications.

Keywords: Carbon quantum dots, Zinc doping, Hydrothermal synthesis, Antioxidant activity.

1.INTRODUCTION

Carbon quantum dots (CQDs) are a class of fluorescent carbon-based nanomaterials that have attracted substantial attention due to their small size (<10 nm), tunable photoluminescence, good aqueous solubility, and low cytotoxicity [1]. Since their discovery in 2004 during the purification of single-walled carbon nanotubes, CQDs have been widely studied for applications in bioimaging, drug delivery, photocatalysis, and biosensing . Unlike conventional semiconductor quantum dots, carbon-based QDs offer the advantages of high biocompatibility and environmental friendliness [2]. CQDs can be synthesized from a variety of carbon-rich precursors using top-down or bottom-up methods. Among these, hydrothermal synthesis is considered a green and cost-effective approach that allows easy doping with heteroatoms or metal ions. [3].The incorporation of metal dopants into CQDs significantly alters their physicochemical and biological properties. Zinc (Zn), a biologically essential trace element, has been shown to improve antioxidant activity when introduced into nanomaterials . Zn-doped CQDs (Zn-CQDs) have thus emerged as a promising candidate for therapeutic applications, particularly in the management of oxidative stress. Carboxylic acid combination with zinc nitrate in a hydrothermal environment facilitates the formation of Zn-CQDs with surface functionalities such as hydroxyl, amine, and thiol groups, which contribute to the bioactivity and stability of the nanomaterials . These surface groups play key roles in modulating enzyme inhibition, metal chelation, and radical scavenging activities [4]. Antioxidant therapies have been extensively explored to mitigate these effects [5]. In this context, we report the synthesis of Zn-CQDs using eco-friendly hydrothermal route and confirm their formation by characterisation and evaluating its biological activities, focusing on their antioxidant potential.

2.MATERIALS AND METHODS

2.1 SYNTHESIS OF Zn-CQDS

CQDs were synthesized hydrothermally by dissolving the precursors in distilled water. The solution was transferred to a Teflon-lined autoclave and heated at 180°C for 6 hours. The product was cooled, filtered, and purified .[6]

2.2 CHARACTERIZATION

FT-IR spectra of the sample was recorded on a FT-IR spectrometer (ACIC, Thiruchirapalli). The morphology of nanoparticles was analysed at HRTEM facility, PSG, Coimbatore.

2.3 BIOLOGICAL ASSAYS

Antioxidant capacity was measured by the phosphomolybdenum method, with results expressed as ascorbic acid equivalents.[7]

3.RESULTS AND DISCUSSION

3.1 Fourier Transform Infrared (FTIR) spectroscopy.

The chemical structure and surface functional groups of the synthesized Zn-CQDs were examined using Fourier Transform Infrared (FTIR) spectroscopy. The FTIR spectrum confirmed the presence of abundant oxygen- and nitrogen-containing functional groups on the surface of the carbon quantum dots. These functional groups originate from the carbon precursor and the nitrogen-containing dopant employed during hydrothermal synthesis and remain attached to the nanoparticle surface after carbonization.[8]

3.2 TEM analysis

The morphology and structural characteristics of the synthesized CQDs were examined using high-resolution transmission electron microscopy (HRTEM).The HRTEM images reveal that the CQDs are predominantly spherical in shape with a uniform and well- dispersed distribution, .At lower magnification (20 nm scale), a large number of ultrafine nanoparticles are visible, indicating successful formation of quantum-sized carbon dots. The particle size is estimated to be in the range of 5 nm, confirming their nanoscale dimensions.The HRTEM results confirm the successful synthesis of monodispersed, spherical, CQDs with nanoscale size. These features are highly favorable for optical properties, fluorescence behavior, and bioimaging applications.[9]

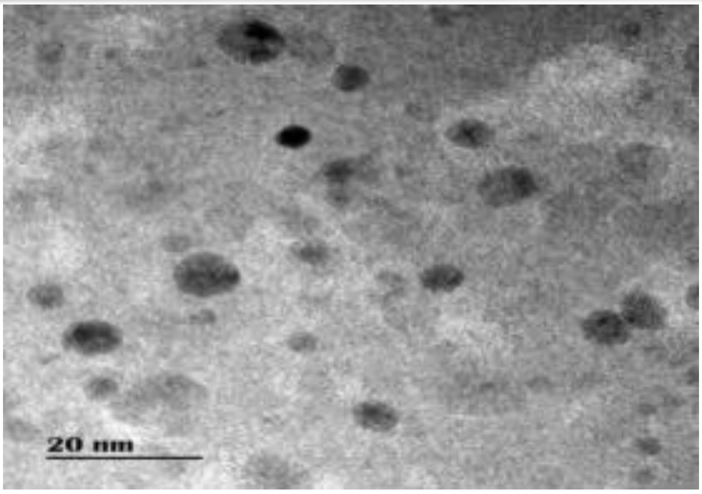

Figure.1- TEM Image Of Carbon Quantum Dots

3.5 ANTIOXIDANT ACTIVITY

The total antioxidant capacity of the extract was evaluated by the phospho-molybdenum method, according to the procedure described by Prieto et al.The absorbance of the solution was measured at 695 nm using a UV-VIS spectrophotometer against blank after cooling to room temperature. The total antioxidant activity is expressed as the number of gram equivalent of ascorbic acid. [10].The results obtained are listed in the table below

Standard	Concentration Ascorbic acid (µg/ml)	Absorbance at 695 nm
S1	100	1.713
S2	200	2.239
S3	300	2.678
S4	400	3.073
S5	500	3.531

Sample code	Absorbance at 695 nm	Concentration of antioxidants (µg/mg)
S1	1.973	148.27

Table.1 Results of Antioxidant activity of synthesized CQDs

Zn-CQDs displayed significant antioxidant activity (148.27 µg/mg AAE), confirming their potential to scavenge free radicals.

CONCLUSION

Zn-CQDs synthesized from the mentioned precursors demonstrate promising antioxidant properties. Comprehensive characterization confirmed the quantum dots' amorphous structure, functional surface groups, and elemental composition. Zn-CQDs demonstrated promising antioxidant capacity , suggesting their potential as therapeutic agents in oxidative stress. Future work may focus on improving bioactivity via surface functionalization or targeting delivery mechanisms.

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