Green synthesis of carbon quantum dots using natural plant extracts and optimization of optical properties

Author's: Habibolah Shahvali[1], Asghar Jamshidi Zavaraki[2] , Mohamad Mehdi Ochi [3]
[1]Master's student in Nano photonics Faculty of Intelligent Systems, University of Tehran , Email: Habib.shahvali@ut.ac.ir
[2]Assistant Professor, Department of Nano photonics Faculty of Intelligent Systems, University of Tehran, Jamshidi.zavaraki@ut.ac.ir
[3]Assistant Professor, Department of Biological Sciences Faculty of Biological Sciences, University of Tehran, MMOjie@ut.ac.ir

ABSTRACT

In this study, a facile, eco-friendly and cost-effective method was developed for the synthesis of fluorescent carbon quantum dots (CQDs) using a mixture of cherry extracts (as carbon precursors), leek and savory (as doping agents) and without the use of any chemicals. The synthesis was carried out via a hydrothermal method at different temperatures (170–180 °C) and reaction times. The optical properties were characterized using UV-Vis and photoluminescence (PL) spectroscopy, while FTIR was used to study the surface functional groups. Our results show that the optical behavior of the synthesized CQDs can be tuned by changing the synthesis parameters, resulting in light emission from blue to green. This work highlights the potential of using common agricultural wastes to fabricate fluorescent nanomaterials for future sensing and optical applications.

Keywords: *Green synthesis, plant mixing, plant-based doping, sensing and medical application, development of optical properties.*

1. *INTRODUCTION*

According to research, green synthesis is one of the main research priorities in the field of quantum dots, biotechnology, diagnostics and medical imaging; therefore, due to its topical importance and interestingness, we synthesized a sample of such carbon dots in green form with new materials and plants, and the optical results obtained from absorption and emission analyses were at a desirable level. Our primary reference and basis for green synthesis was the article (2025). Salman, B. I, in which water or apricot extract was used for synthesis with a quantum efficiency of about 37%, which was very good and acceptable. The synthesis was done with plant and fruit ingredients and combinations, and we also selected ingredients that had either not been used before or one of them had been used individually. Ultimately, our selected raw materials included sour cherries, leeks, and savory, Carbon dots synthesized using a green method have negligible toxicity due to the use of plant-biological and non-chemical sources, and therefore are of particular importance in medical and biological applications, as no chemicals were used in this research. Following the research conducted by researchers in this field and with a creative idea of using a combination of several plants and fruits, we successfully conducted this research, which will pave the way for new research in the future.

2. MATERIALS AND METHODS

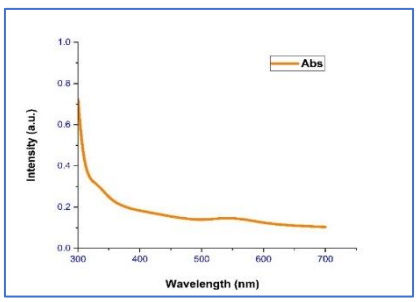
Carbon dots were synthesized by hydrothermal method with a volume of 10 ml of cherry, chive and savory extracts in 25 ml of deionized water, which was homogenized on a stirrer in a semi-dark space at 400 rpm. Then it was transferred to an autoclaved Teflon container and finally carried out for 6 hours at 170 ° C. After the synthesis time was over and the container reached room temperature, the solution was centrifuged at 14,000 rpm and purified with a 0.22 µm filter, According to the starting materials in Figure (1).

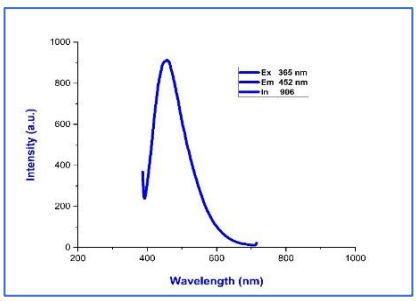
Figure (1): *Symbolic images of the starting materials used in the green synthesis*

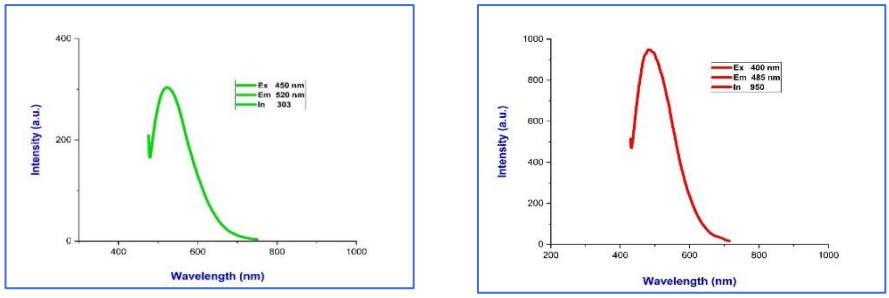
3. DISCUSSION AND CONCLUSION

Optical and quantum results from PL, UV-vis, FT-IR analyses showed that the synthesis and doping operations were optimally performed and led to the desired absorption and emission, and ***various functional groups such as C=O, C-N, OH*** *were created on the surface of the carbon dots, which caused the dependence on the excitation wavelength and the desired light emission towards* ***longer wavelengths (red shift)****, meaning that under these specific conditions, the largest number of luminescence centers and controlled structural defects were created for light production.*

(A)







(B)

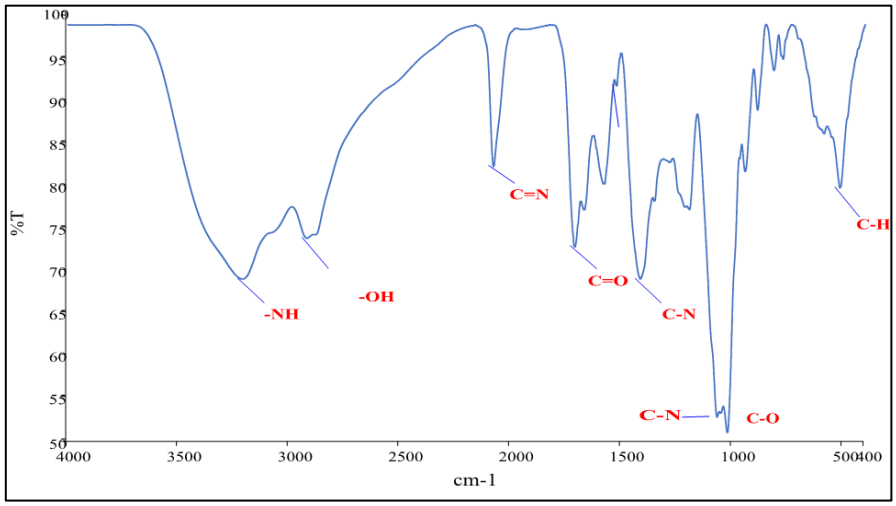


Figure (2): *The graphs on the left (A) correspond to UV-Vis and PL analyses at 360-400 and 450 nm and the graph on the right (B) corresponds to FT-IR analysis.*

The graphs in Figure (2) prove this. The ***emission wavelengths at excitation*** *of 365, 400 and 450 nm were* ***recorded at 452, 485 and 520 nm, respectively, at 906, 950 and 303 nm, and QY=62%*** *was also calculated based on the reliable reference of quinine sulfate.*

REFERENCES

[1] *Gómez-Pérez, A., Antonio-Pérez, A., & García-Ruiz, C. (2025). Fungal biomass as a sustainable precursor for the production of carbon dots. *Biotechnology for Sustainable Materials, 2*(1), 10. https://doi.org/10.1186/s44316-025-00033-2*

[2] *Pandit, P., Das, S., & Das, P. K. (2025). Green Carbon Dots: Synthesis, Characterization, Properties and Biomedical Applications. *Journal of Materials Chemistry B*. https://doi.org/10.1039/D5TB00113A*

[3] *Salman, B. I. (2025). Synthesis of highly fluorescent green carbon quantum dots from Prunus armeniaca for the determination of lisinopril in human plasma. Scientific Reports, 15, 32502. https://doi.org/10.1038/s41598-025-17535-8*

[4] *Singh, S., Kumari, S., Singh, A. K., Kumar, M., Singh, R. K., & Singh, R. (2025). Green Synthesis of Carbon Nanoparticles (CNPs) from Biomass for Biomedical Applications.*Biotechnology for*

Sustainable Materials,2(1),7. https://doi.org/10.1186/s44316-025-00030-5*

[5] *Li, Y., Lu, H., & Li, H. (2024). Recent advances in green synthesis of carbon dots for biomedical applications. *Journal of Materials Science & Technology, 127*, 145-165. https://doi.org/10.1016/j.jmst.2023.08.018*

[6] *Yue, Y., Li, Y., & Wang, X. (2023). Green synthesis of carbon dots from food waste for sensitive detection of heavy metal ions. *Food Chemistry, 405*, 134820. https://doi.org/10.1016/j.foodchem.2022.134820*

[7] *Sun, Y., Huang, Y., Wang, Y., & Li, J. (2022). One-step green synthesis of carbon quantum dots from citric acid for bioimaging and drug delivery. *Materials Science and Engineering: C, 135*, 112867. https://doi.org/10.1016/j.msec.2022.112867*

[8] *Kumar, A., Yadav, S., & Singh, B. (2022). Green synthesis of nitrogen-doped carbon dots from plant biomass for enhanced photocatalytic activity. *Journal of Alloys and Compounds, 917*, 165439. https://doi.org/10.1016/j.jallcom.2022.165439*

[9] *Atchudan, R., Zehnpfennig, J., Barhoum, A., & Min, J. (2021). Green synthesis and characterization of carbon dots from agricultural waste for fluorescent sensing applications. *Carbohydrate Polymers, 253*, 117260. https://doi.org/10.1016/j.carbpol.2020.117260*

[10] *Sharma, S., Singhal, R., Gopinath, P., & Sharma, S. K. (2021). Green synthesis and characterization of highly fluorescent carbon dots from rice straw for optical sensing and imaging. *Journal of Luminescence, 234*, 117954. https://doi.org/10.1016/j.jlumin.2021.117954*

" I would like to thank my valuable professors who helped me present this article."