



Microwave-assisted Green Synthesis of Carbon Dots from Medicinal Plants: Structural, Morphological, and Optical Insights

Aparna Unnikrishnan and J. Balavijayalakshmi*

Department of Physics, PSGR Krishnammal College for Women, Coimbatore, TN, India

Received: 23.10.2025 Accepted: 28.11.2025 Published: 30.12.2025

*balavijayalakshmiroopa@gmail.com



ABSTRACT

In this study, green carbon dots (GCDs) were synthesized via a microwave-assisted route using three medicinal plants, *Bacopa monnieri*, *Datura metel*, and *Phyllanthus niruri*, as natural carbon precursors. The approach offers an eco-friendly, rapid, and reproducible alternative to conventional synthesis routes. The optical, structural, and morphological characteristics of the GCDs were systematically investigated using UV–Vis spectroscopy, FT-IR, XRD, FE-SEM, and EDAX analyses. The UV–Vis spectra revealed strong π – π^* and n – π^* transitions, confirming the presence of conjugated carbon networks and surface oxygen functionalities. FT-IR spectra confirmed hydroxyl, carbonyl, and carboxyl groups, imparting hydrophilicity and stability. XRD analysis indicated amorphous graphitic structures with variable degrees of graphitization among the samples. FE-SEM micrographs demonstrated distinct morphologies: *Bacopa monnieri*-derived GCDs were uniformly spherical; *Datura metel*-based GCDs exhibited irregular flake-like structures; and *Phyllanthus niruri*-derived GCDs formed densely packed, porous aggregates. EDX spectra confirmed carbon–oxygen dominance with trace mineral elements unique to each precursor. The comparative analysis reveals that phytochemical composition and precursor nature significantly influence the surface chemistry and optical response of the GCDs. The resulting materials show promise for diverse applications in bioimaging, catalysis, environmental remediation, and drug delivery. This work highlights the potential of medicinal plant-derived precursors as sustainable feedstocks for producing high-quality carbon nanomaterials through a green, energy-efficient synthesis route.

Keywords: Green carbon dots; Microwave-assisted method; UV–Vis spectra; Medicinal plants.

1. INTRODUCTION

Quantum dots (QDs) are nanoscale semiconductor particles with reduced dimensions that impart distinctive optical and electronic behaviors due to quantum confinement. The energy levels become discrete when the particle size decreases to the nanometer scale, leading to size-dependent photoluminescence. These properties define QDs as unique materials well-suited for inclusion into various optoelectronics devices, photovoltaic devices, bioimaging, and drug delivery systems. However, traditional QDs, which are synthesized with cadmium, lead, selenium, and other toxic heavy metals, pose numerous environmental and biological risks (Kumar *et al.* 2017). This has led to concerns of safety, particularly in biomedical applications, prompting the search for non-toxic materials. In this context, carbon quantum dots (CQDs) have emerged as a green substitute for the traditional QD technology. These nanometer-sized, quasi-spherical carbon particles have significant properties, such as strong light absorption, chemical inertness and stability, non-toxicity, and biocompatibility, making them suitable for photocatalysis, biosensing, medical diagnostics,

bioimaging, drug delivery, and environmental monitoring (Liu *et al.* 2017). CQDs possess diverse surface functional groups, including carboxyl, hydroxyl, and amine groups, which enhance their water solubility and chemical stability while also enabling further modification for broader industrial and biomedical applications. The preparation procedure of CQDs can be divided into bottom-up and top-down methods. Top-down methods include the breakdown of large carbon forms, including graphite, by laser or electrochemical oxidation. On the other hand, the bottom-up methods include the construction of CQDs from precursor organic molecules through heat treatment, arc discharge, hydrothermal process, as well as microwave synthesis routes. Among these green synthesis methods, those employing natural, renewable precursors have received much attention due to their several advantages. Synthesis of GCDs from natural precursors is essentially an environmentally friendly approach due to the incorporation of plant materials containing carbon and bioactive molecules. Especially, medicinal plants are enriched with phytochemicals such as phenolics, flavonoids, alkaloids, and terpenoids, which can be used as a carbon source as well as capping agents. Apart from

being incorporated into the carbon framework, these phytocompounds improve the properties and functions of sensing applications. In the present work, GCDs were synthesized for biomedical and environmental applications using *Bacopa monnieri*, *Phyllanthus niruri*, and *Datura metel* as natural starting materials. These medicinal plants are widely used as therapeutic agents and have rich phytochemical composition (Gao *et al.* 2020). It is used in traditional Indian medicine, specifically in Ayurveda. *Bacopa monnieri* possesses cognition-enhancing and neuroprotective properties, and its phenolic and flavonoid constituents contribute to the formation and stabilization of GCD. *Phyllanthus niruri* is well known for its hepatoprotective and antioxidant effects; besides, GCDs are characterized by high polyphenolic contents that improve the photoluminescent properties of the material (Mehta *et al.* 2014). However, *Datura metel*, a plant with various bioactive compounds such as alkaloids and flavonoids, can enhance the carbonization process as well as have passivation effects, and improve the fluorescence intensity. This method also provides control over the conversion of surface functionalization, offering better quantum yields and better optical characteristics. In addition, the microwave-assisted synthesis is energy-saving and easily reproducible even at a large scale, hence making the GCD synthesis an excellent and environmentally friendly approach (Landa *et al.* 2022). In this paper, GCDs are synthesized from *Bacopa monnieri*, *Phyllanthus niruri*, and *Datura metel* employing microwave-assisted synthesis. The synthesized GCDs are systematically studied to explore the structural, optical, and surface features of the materials. This research aims to explore how these medicinal plants can effectively act as natural precursors for synthesizing GCDs through green nanotechnology, thereby supporting sustainable large-scale production of the nanomaterial and encouraging environmentally friendly applications of nanotechnology in biosensing, bioimaging, environmental monitoring, and energy conversion.

2. MATERIALS AND METHODS

2.1 MATERIALS

Bacopa monnieri, *Datura metel*, and *Phyllanthus niruri* leaves were sourced from recognized Ayurvedic suppliers in Coimbatore, Tamil Nadu, India. Prior to synthesis, the leaves were rinsed thoroughly with distilled water ($18.2\text{ M}\Omega\text{ cm}$; Milli-Q system) to eliminate dust and impurities. For each microwave-assisted reaction, 10 g of freshly cut leaves were combined with 50 mL of distilled water (Merck Pvt. Ltd., India). All solvents and reagents were of analytical grade and used as received without further purification.

3. PREPARATION OF CARBON DOTS

Bacopa monnieri, *Datura metel*, and *Phyllanthus niruri* were used as plant sources for synthesizing carbon dots through the microwave method. 10 g of *D. metel* leaves, and 50 mL of distilled water were subjected to microwave treatment for 15 min with a power level of 420 W (Figure 1). The same procedure was repeated for *P. niruri* and *B. monnieri* as well. The extracted carbon dot solution was characterized using UV-Vis and FT-IR techniques to investigate its optical and functional properties. The filtered solution was lyophilized and characterized further using XRD, FE-SEM, and EDAX techniques to investigate its structural, morphological, and elemental properties, respectively.

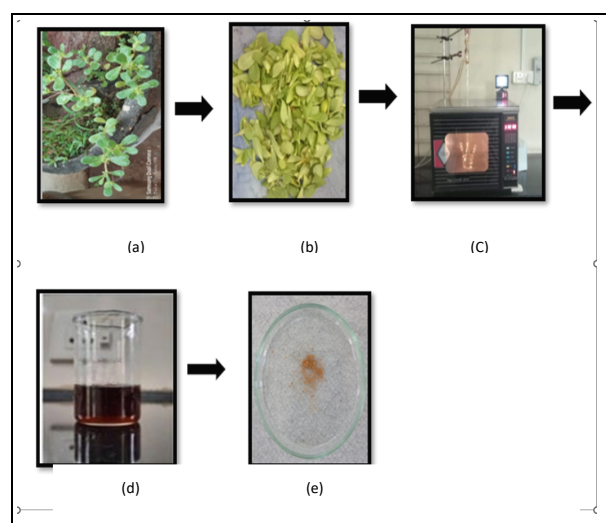


Fig. 1: Synthesis of GCD using *Bacopa monnieri*. (a) Fresh *B. monnieri*, (b) 10 g of *B. monnieri* leaves, (c) Microwave treatment of the mixture, (d) Extracted solution, and (e) Lyophilized solution

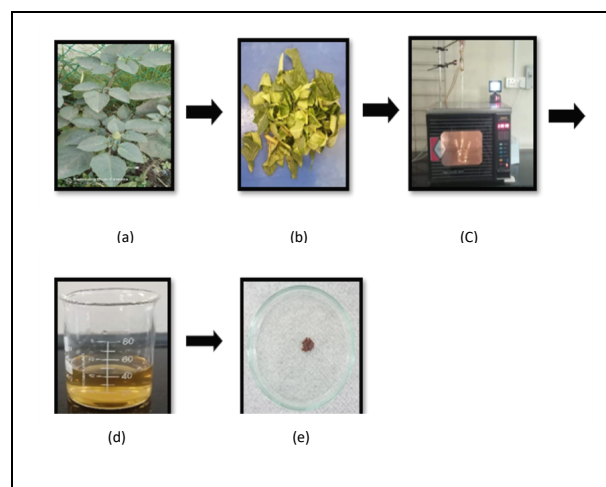


Fig. 2: Synthesis of GCD using *Datura metel*. (a) Fresh *D. metel*, (b) 10 g of *D. metel* leaves, (c) Microwave treatment of the mixture, (d) Extracted solution, and (e) Lyophilized solution

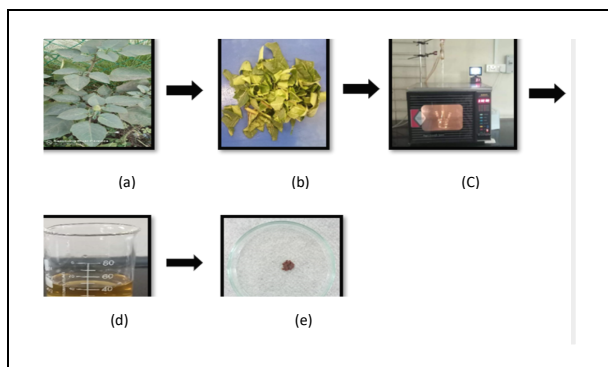


Fig. 3: Synthesis of GCD using *Phyllanthus niruri*. (a) Fresh *P. niruri*, (b) 10 g of *P. niruri* leaves, (c) Microwave treatment of the mixture, (d) Extracted solution, and (e) Lyophilized solution

4. CHARACTERIZATION TECHNIQUES

The prepared carbon dots' crystalline structure was analyzed using an X'Pert³ PANalytical diffractometer, while Fourier transform infrared (FT-IR) spectra were recorded using a Shimadzu IRAffinity-1 spectrophotometer. Scanning electron micrographs (SEM) were obtained using ZEISS SIGMA to study the sample's morphology. The composition of the elements in the sample was determined through Energy Dispersive X-ray Spectroscopy (EDX). A Cary 60 UV-Vis spectrophotometer was used for UV-Vis absorption analysis.

5. RESULTS AND DISCUSSION

5.1 UV-Vis Spectral Analysis

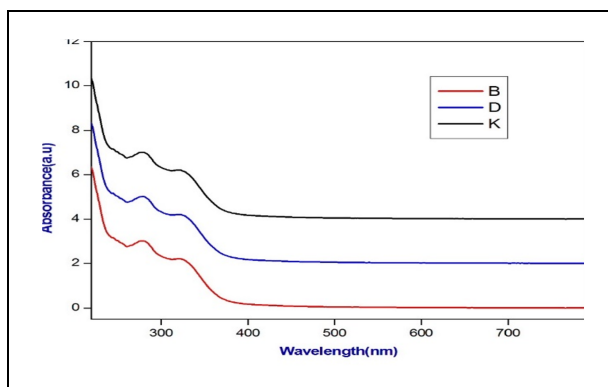


Fig. 4: UV-Vis spectra of *Bacopa monnieri* (B), *Datura metel* (D), and *Phyllanthus niruri* (K)

UV-Vis spectra of GCDs revealed typical absorption bands of carbon-based nanomaterials, as shown in Figure 4. For the three spectra, all of them show high absorbance in the UV region and then decrease up to the visible region (Atchudan *et al.* 2017). This behavior is characteristic of CQDs and is mainly due to $\pi-\pi^*$ electronic transitions from C=C bonds in aromatic

rings and $n-\pi^*$ transitions from hydroxyl (-OH), carboxyl (-COOH), and carbonyl (-C=O) functional groups. The absorption spectrum of *B. monnieri* represents a clear peak of 270–280 nm which shows the presence of $\pi-\pi^*$ transition due to the presence of aromatic bonds. However, the absorbance intensity of this sample has lower value than the other two samples which indicate that this sample has fewer conjugated carbon structures or less functional groups present on the surface. The peak of *D. metel* looks slightly red-shifted in comparison with the peak of *B. monnieri*. The peak appears around 280–290 nm, which may be attributed to a more extensive π -conjugation system or a higher degree of surface oxidation.

The compounds analyzed from *P. niruri* show the highest GCD adsorption intensity; the dominant peak at 270–280 nm is also similar to *B. monnieri* (Bhamore *et al.* 2019). The UV measurements also reveal an enhanced absorption in the UV region, which may be attributed to a higher degree of graphitization or a denser concentration of surface functional groups, such as the polyphenols present in the plant material used in this study, namely *P. niruri*.

The extended absorption bands in the range of 200–400 nm in all samples reaffirm both the formation of $\pi-\pi^*$ and $n-\pi^*$ transitions. Specifically, there is minimal light absorption in the UV-Vis spectra beyond 400 nm in the visible region, indicating the absence of scattering associated with surface plasmon resonance, which is characteristic of metallic nanoparticles but not carbon-based nanomaterials (Qu *et al.* 2020). The variations in absorption peak intensities and peak positions reflect differences in their surface chemistry and carbon frameworks, offering insights into their structural and optical properties. The distinct optical behaviors of the three GCDs suggest that the choice of precursor material significantly influences their absorption characteristics.

5.2 FT-IR Spectral Analysis

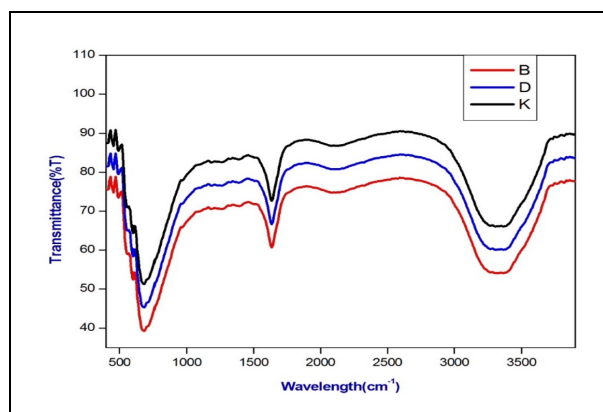


Fig. 5: FTIR spectra of *B. monnieri* (B), *D. metel* (D), and *P. niruri* (K)

The FT-IR spectra of the green carbon dots synthesized using the three plant sources are presented in Figure 5. The set of peaks is specific to the presence of functional groups on their surfaces. The broad absorption band recorded at 3200–3600 cm^{-1} in all three spectra belongs to the O–H stretching frequency of hydroxyl groups. This shows that there are many hydroxyl groups on the surface of the GCDs, which improve the hydrophilic and biocompatible properties of the material (Bhamore *et al.* 2018). The intensity of this band is maximum for *B. monnieri* and minimum for *P. niruri*, indicating that there are variations in the density of the surface hydroxyl group between the three samples. This variation might have been due to the variation in the phytochemical contents of the plant precursors.

In the range 2800 to 3000 cm^{-1} , there are weak C–H stretching frequencies from aliphatic or aromatic hydrocarbons, showing the presence of sp^3 and sp^2 hybridized carbons, respectively. The higher concentration of such chains is attributed to *B. monnieri*, which contains more aliphatic chains than *D. metel* and *P. niruri*. The absorption bands in the 1600–1700 cm^{-1} range correspond to C=O vibrations, which are associated with carbonyl or amide groups, and these groups enhance the photoluminescent properties of the GCDs and enable their interaction with biomolecules. This peak is well defined in all the samples; especially, *P. niruri* shows a higher carbonyl functional group (Murugan *et al.* 2019). A peak at 1400–1500 cm^{-1} can also be seen, which points to C=C stretching of aromatic regions. Partial graphitization, which occurred through this band, is present in all three samples and has an influence on the optical and electronic properties of the GCDs. The relative intensity of this band is found to be higher for *P. niruri* than for the other samples and indicates that the graphitic structure is well formed.

Below 1000 cm^{-1} , intense bands were recorded, and these can be denoted as C–O stretching and bending of carboxyl and ester group. These functional groups are important for the GCDs water solubility and also provide the ability to easily functionalize (Sharma *et al.* 2020). The absorption intensity of the *D. metel* sample is slightly higher in this area than that perceived for the other two samples of this compound, which indicates that it has more intense oxygen-containing functional groups. Therefore, the FT-IR spectra confirm that the GCDs derived from the three plant sources have different surface chemistries in terms of the concentration and type of functional groups present, although the characteristics are very similar. The prominent hydroxyl, carbonyl, and aromatic functionalities across all samples highlight their eco-friendly synthesis and potential for a wide range of applications.

5.3 XRD Structural Analysis

The XRD patterns of the GCDs, depicted in Figure 6, reveal the structural details of the crystalline and amorphous forms that are present in the GCDs synthesized from *B. monnieri* and *D. metel*. A peak around a 2θ value of $\sim 22^\circ$ can be related to the presence of the (002) plane of graphitic carbon for all three investigated samples. This peak is related to the layer distance or the interlayer spacing of graphitic sheets and confirms the existence of a graphitic-like phase in the GCDs, but it is not very crystalline. Therefore, *D. metel* has the most intense and sharpest (002) peak than *B. monnieri* and *P. niruri*, indicating the highest degree of graphitization and the most developed graphitic structure in *D. metel*.

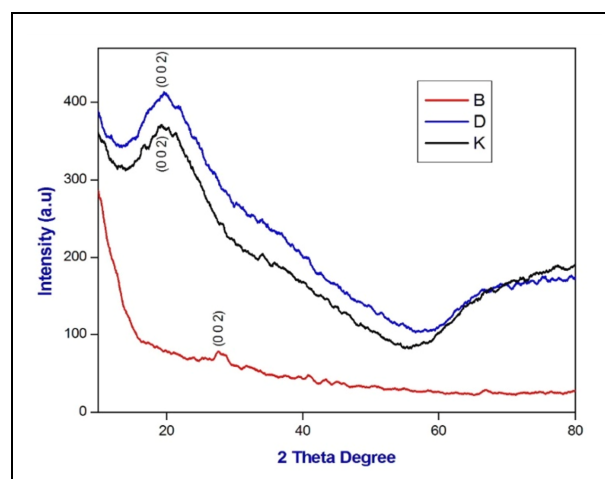


Fig. 6: XRD spectra of *B. monnieri* (B), *D. metel* (D), and *P. niruri* (K)

On the other hand, the XRD pattern of *B. monnieri* (B) shows a broader and less intense (002) peak, indicating a more amorphous structure with less well-ordered graphitic domains. This higher degree of disorder may contribute to unique surface properties, potentially enhancing functionalization. Meanwhile, the XRD graph of *P. niruri* (K) exhibits an intermediate intensity and sharpness for the (002) peak, suggesting a moderate level of graphitization. Furthermore, there are secondary small peaks in the 40–50° range in the XRD patterns, which could be associated with crystalline phase domains or the formation of graphitic nanoparticles within the carbon matrix (Atchudan *et al.* 2018). These are actually prominent in the *D. metel* sample, which adds to the relatively high crystallinity of this sample compared with the other two samples. Overall, the XRD analysis confirms that the GCDs synthesized possess a predominantly amorphous structure with varying degrees of graphitization. The differences in the crystallinity and structural ordering are likely influenced by the unique phytochemical compositions of each plant precursor, affecting the GCDs' potential performances.

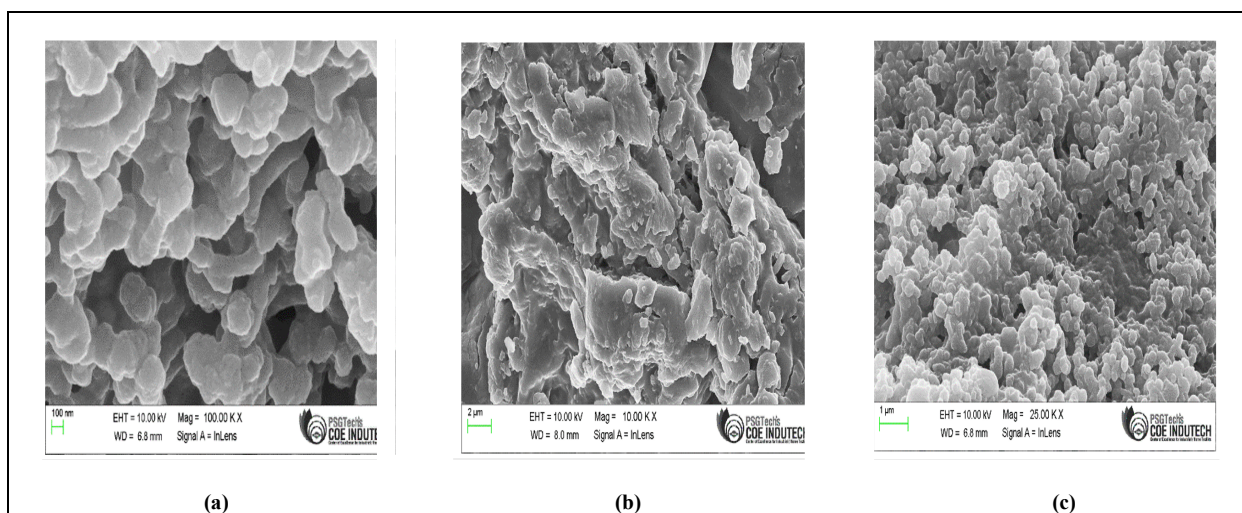


Fig. 7: FE- SEM images of: (a) *Bacopa monnieri*, (b) *Datura metel*, and (c) *Phyllanthus niruri*

5.4 FE-SEM Analysis

Figure 7 represents the FE-SEM image of the synthesized green carbon dots. It was found that the morphology is nanostructured. This attribute can be considered outstanding since the image reveals the presence of predominantly spherical-shaped particles with a relatively narrow range of size distribution in the nanometer scale, and this confirms proper control of the atmosphere as it was during the synthesis process (Ding *et al.* 2019). Morphological analysis shows that these carbon dots possess smooth and compact structures with few defects or deformations, thereby confirming the effectiveness of the green synthesis method. This indicates that while the particles are strongly interacting with one another, the interfacial thickness is small and has not caused significant aggregation to occur, and this is important for improving the particles' optical and functional properties.

The high-resolution imaging also shows how packed the particles are, with small vacuities or spaces visible in some areas. They may lead to a porous structure that is advantageous for a large surface area, and with applications such as adsorption, catalytic activity, and energy storage.

Based on these findings, the successful formation of green carbon dots from *B. monnieri* is confirmed, exhibiting nanoscale morphology with high structural and surface smoothness (Yang *et al.* 2017). These features are very important for many applications where stable and reproducible nanomaterials are needed, such as bio-imaging, drug delivery, and environmental applications. The well-defined structure of the carbon dots obtained from *B. monnieri* highlights the efficiency of the green synthesis route and the feasibility of preparing optimal carbon dots.

FE-SEM image of green carbon dots obtained from *D. metel* reveals a completely different morphology with surface structures that are uneven and irregular (Pooja *et al.* 2019). It illustrates an agglomerated stratification of differently sized particles forming clusters with a rough surface. They exhibit a flaky or fragmented structure and are indicative of the intrinsic traits of carbon-based materials. The rough porous nature of the material might also have an association with the precursor plant source and microwave processes in synthesizing green carbon dots.

The evidence from individual particles appears non-homogeneous, which may indicate heterogeneous nucleation. The interconnected arrangement and closeness can result in increased surface area. The increased contrast present in the image is indicative of clear boundaries and interfaces existing, which might indicate variations in elemental composition and the presence of functional groups arising from green synthesis. Moreover, the morphology implies that these carbon dots may exhibit quantum confinement effects in their nanostructures, leading to improved optical properties, such as enhanced photoluminescence.

The FE-SEM image of the green carbon dots synthesized using *P. niruri* illustrates a very agglomerated morphology composed of packed clusters of particles. It has a surface that seems quite uneven, with distinct granular structures of varying sizes and shapes. The carbon-based material holds a highly porous and interconnected network, indicating a high degree of aggregation during the synthesis process. This can be attributed to the natural properties contributed by the precursor plant material, as well as the synthesis conditions.

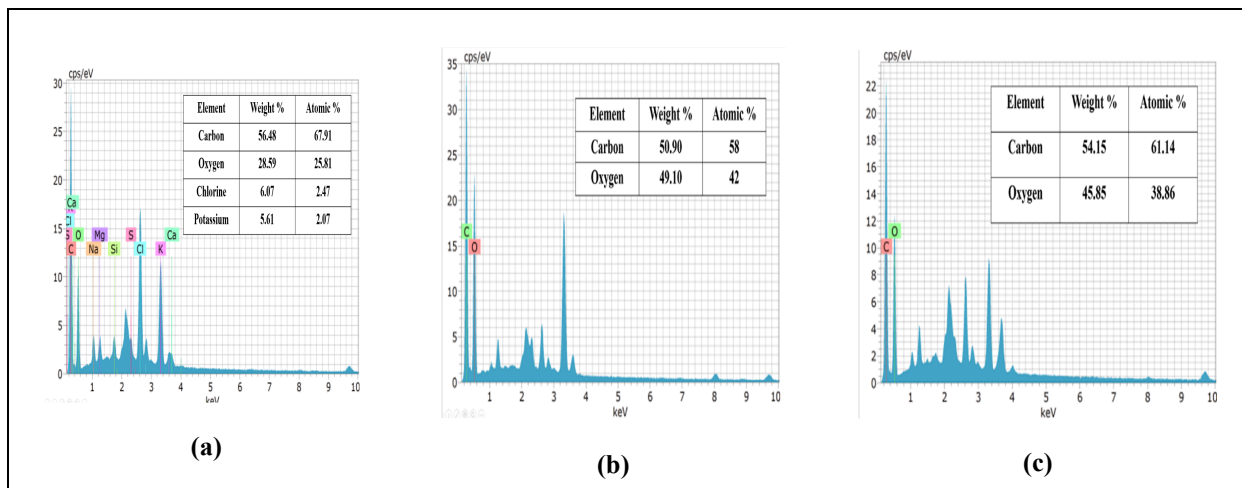


Fig. 8: EDAX analysis of: (a) *Bacopa monnieri*, (b) *Datura metel*, and (c) *Phyllanthus niruri*

5.5 EDAX Analysis

Figure 8 shows the EDAX spectra, which reveal compositional differences among the green carbon dots derived from the three plant sources. The dots consist predominantly of carbon and oxygen, indicating their organic nature and the presence of surface functional groups.

In the carbon dots derived from *B. monnieri*, the highest percentage of carbon weight is 56.48%, with 28.59% oxygen. Traces of chlorine (6.07%), potassium (5.61%), calcium, magnesium, sodium, silicon, and sulfur were also found (Architha *et al.* 2021). This shows the variety of minerals provided by *B. monnieri*, which could get incorporated into the carbon dots, likely during the synthesis process. Such trace elements are helpful in possibly enhancing the catalytic and biological activities.

On the contrary, the carbon dots from *D. metel* have values indicating 50.90% carbon and 49.10% oxygen. This composition of carbon and oxygen suggests considerable oxidation, which is likely to produce various oxygen-containing functional groups such as hydroxyl, carboxyl, and carbonyl groups. Such a profile of functional groups enhances solubility, fluorescence effectiveness, and bio-compatibility of carbon dots.

The carbon dots produced from *P. niruri* have 54.15% carbon and 45.85% oxygen contents, implying a marginally higher carbon-to-oxygen ratio than those derived from *D. metel* (Boobalan *et al.* 2020). Hence, the high carbon indicates that the carbon dots from *P. niruri* have a more hydrophobic core with oxygen functionalities on the surface for better dispersibility in aqueous solutions and enhanced stability.

These three carbon dots differ in elemental composition and thus emphasize the influence of precursor plant material on their structural and chemical properties. In addition to their simple structure, *D. metel* carbon dots and *P. niruri* carbon dots may have uniformity and high potential for charges for controlled surface modifications. This variation in elemental composition can significantly affect their fluorescence, stability, and potential interactions with biological or environmental systems, making carbon dots distinct from one another for specific applications.

6. CONCLUSION

Green carbon dots synthesized from *Bacopa monnieri*, *Datura metel*, and *Phyllanthus niruri* demonstrated differences in structure, morphology, and chemical composition as confirmed by UV-Vis, FT-IR, XRD, EDAX, and FE-SEM analyses. Spherical, uniformly distributed particles from *B. monnieri* exhibit good structural integrity and low aggregation, making them perfect candidates for bioimaging or drug delivery. In comparison, flake-like and porous structures from *D. metel* and tightly packed clusters from *P. niruri* provide greater surface areas with an increase in structural roughness, thereby improving their potential to be used for catalytic and environmental applications. The different characteristics exhibited by these GCDs testify to the influence that natural precursors and synthesis conditions have on their morphology, surface chemistry, and functionality. Thus, this work portrays the effectiveness of green synthesis methods in producing environmentally sustainable, high-quality carbon nanomaterials with versatile applications across various industries, paving the way for further research and development in green nanotechnology.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the DST-FIST, New Delhi, for providing infrastructure support for this work.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

COPYRIGHT

This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).



REFERENCES

- Architha, N., Ragupathi, M., Shobana, C., Selvankumar, T., Kumar, P., Lee, Y. S. and Selvan, R. K., Microwave-assisted green synthesis of fluorescent carbon quantum dots from Mexican Mint extract for Fe³⁺ detection and bio-imaging applications, *Environ. Res.*, 199, 111263 (2021). <https://doi.org/10.1016/j.envres.2021.111263>
- Atchudan, R., Edison, T. N. J. I., Perumal, S. and Lee, Y. R., Indian gooseberry-derived tunable fluorescent carbon dots as a promise for in vitro/in vivo multicolour bioimaging and fluorescent ink, *Acs Omega*, 3(12), 17590-17601 (2018). <https://doi.org/10.1021/acsomega.8b02463>
- Atchudan, R., Edison, T. N., Chakradhar, D., Perumal, S., Shim, J. J. and Lee, Y. R., Facile green synthesis of nitrogen-doped carbon dots using Chionanthus retusus fruit extract and investigation of their suitability for metal ion sensing and biological applications, *Sens. Actuators B: Chem.*, 246, 497-509 (2017). <https://doi.org/10.1016/j.snb.2017.02.119>
- Bhamore, J. R., Jha, S., Park, T. J. and Kailasa, S. K., Green synthesis of multi-colour emissive carbon dots from Manilkara zapota fruits for bioimaging of bacterial and fungal cells, *J. Photochem. Photobiol. B: Biol.*, 191, 150-155 (2019). <https://doi.org/10.1016/j.jphotobiol.2018.12.023>
- Bhamore, J. R., Jha, S., Singhal, R. K., Park, T. J. and Kailasa, S. K., Facile green synthesis of carbon dots from Pyrus pyrifolia fruit for assaying of Al³⁺ ion via chelation enhanced fluorescence mechanism, *J. Mol. Liq.*, 264, 9-16 (2018). <https://doi.org/10.1016/j.molliq.2018.05.041>
- Boobalan, T., Sethupathi, M., Sengottuvelan, N., Kumar, P., Balaji, P., Gulyás, B., Padmanabhan, P., Selvan, S. T. and Arun, A., Mushroom-derived carbon dots for toxic metal ion detection and as antibacterial and anticancer agents, *ACS Appl. Nano Mater.*, 3(6), 5910-5919 (2020). <https://doi.org/10.1021/acsanm.0c01058>
- Ding, H., Zhou, X., Qin, B., Zhou, Z. and Zhao, Y., Highly fluorescent near-infrared emitting carbon dots derived from lemon juice and its bioimaging application, *J. Lumin.*, 211, 298-304 (2019). <https://doi.org/10.1016/j.jlumin.2019.03.064>
- Gao, R., Wu, Z., Wang, L., Liu, J., Deng, Y., Xiao, Z., Fang, J. and Liang, Y., Green preparation of fluorescent nitrogen-doped carbon quantum dots for sensitive detection of oxytetracycline in environmental samples, *Nanomater.*, 10(8), 1561 (2020). <https://doi.org/10.3390/nano10081561>
- Kumar, A., Chowdhuri, A. R., Laha, D., Mahto, T. K., Karmakar, P. and Sahu, S. K., Green synthesis of carbon dots from Ocimum sanctum for effective fluorescent sensing of Pb²⁺ ions and live cell imaging, *Sens. Actuators, B: chem.*, 242, 679-86 (2017). <https://doi.org/10.1016/j.snb.2016.11.109>
- Liu, W., Diao, H., Chang, H., Wang, H., Li, T. and Wei, W., Green synthesis of carbon dots from rose-heart radish and application for Fe³⁺ detection and cell imaging, *Sens. Actuators B: Chem.*, 241, 190-198 (2017). <https://doi.org/10.1016/j.snb.2016.10.068>
- Mehta, V. N., Jha, S. and Kailasa, S. K., One-pot green synthesis of carbon dots by using Saccharum officinarum juice for fluorescent imaging of bacteria (Escherichia coli) and yeast (Saccharomyces cerevisiae) cells, *Mater. Sci. Eng.: C*, 38, 20-27 (2014). <https://doi.org/10.1016/j.msec.2014.01.038>
- Murugan, N., Prakash, M., Jayakumar, M., Sundaramurthy, A. and Sundramoorthy, A. K., Green synthesis of fluorescent carbon quantum dots from Eleusine coracana and their application as a fluorescence 'turn-off' sensor probe for selective detection of Cu²⁺, *Appl. Surf. Sci.*, 476, 468-480 (2019). <https://doi.org/10.1016/j.apsusc.2019.01.090>
- Pooja, D., Singh, L., Thakur, A. and Kumar, P., Green synthesis of glowing carbon dots from Carica papaya waste pulp and their application as a label-free chemo probe for chromium detection in water, *Sens. Actuators B: Chem.*, 283, 363-372 (2019). <https://doi.org/10.1016/j.snb.2018.12.027>

Qu, Y., Yu, L., Zhu, B., Chai, F. and Su, Z., Green synthesis of carbon dots by celery leaves for use as fluorescent paper sensors for the detection of nitrophenols, *New J. Chem.*, 44(4), 1500-1507 (2020).

<https://doi.org/10.1039/C9NJ05285B>

Sharma, N., Das, G. S. and Yun, K., Green synthesis of multipurpose carbon quantum dots from red cabbage and estimation of their antioxidant potential and bio-labelling activity, *Appl. Microbiol. Biotechnol.*, 104(16), 7187-7200 (2020).

<https://doi.org/10.1007/s00253-020-10726-5>

Yang, R., Guo, X., Jia, L., Zhang, Y., Zhao, Z. and Lonshakov, F., Green preparation of carbon dots with mangosteen pulp for the selective detection of Fe³⁺ ions and cell imaging, *Appl. Surf. Sci.*, 423, 426-432 (2017).

<https://doi.org/10.1016/j.apsusc.2017.05.252>