Pharmacogn. Res., 2026; 18(4):1103-1111.
https://www.phcogres.com

Review Article

A Review on Green Synthesis of Carbon Nanoparticles and its Biomedical and Wound Healing Applications

Steffy Dominic[1], Perumal Elumalai[1], Rajeshkumar Shanmugam[2,*]

[1]Department of Biochemistry, Cancer Genomics Laboratory, Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, INDIA.
[2]Department of Anatomy, Nanobiomedicine Lab, Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, INDIA.

ABSTRACT

Carbon Nanoparticle (CNPs) shows significant impact in biomedical fields, especially in targeted drug delivery system, cancer therapies and wound healing applications. Green synthesis|| of carbon-based nanoparticle from bio-waste fruit peels, leaves, presents eco- friendly, low cost, high scalability than other chemical and physical method. This review aims to highlights the green synthesis of carbon nanoparticle through various methods, including hydrothermal, microwave assisted, ultrasonification, pyrolysis, hydrothermal and chemical oxidation, chemical vapor oxidation (CVD), Arc discharge, laser ablation, electrospinning, template assisted growth, freeze drying and highlights major forms of carbon nanoparticles such as Carbon Dots (CDs), Carbon Nanotubes (CNTs), Carbon Nanosphere (CNs), Mesoporouscarbon Nanoparticle (MCNs), and Nanodiamonds (NDs) and its biomedical applications. This review focus on role of carbon nanoparticle on wound healing and carbon nanoparticle enhances on collagen deposition, accelerates hemostasis and tissue regeneration. By incorporating both the green synthesis and its biomedical applications emerging the direction for the potent wound healing applications in eco-friendly methods.

Keywords: Biomedical applications, Carbon nanoparticle, Green synthesis, Wound healing.

Correspondence:
Dr. Rajeshkumar Shanmugam
Department of Anatomy, Nanobiomedicine Lab, Saveetha Medical College and Hospital, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-602105, Tamil Nadu, INDIA.
Email: rajeshkumars.sdc@saveetha.com

Received: 21-05-2026;
Revised: 02-06-2026;
Accepted: 13-07-2026.

INTRODUCTION

Nanotechnology has transformed biomedical research and healthcare by providing advanced methods for disease diagnosis, drug delivery systems, and tissue regeneration. Apart from other metallic nanoparticles like gold and silver, the Carbon-Based Nanoparticles (CNPs), including Carbon Dots (CDs) and Carbon Nanotubes (CNTs), are classified into Single-Walled Carbon Nanotubes (SWCNTs) and Multi-Walled Carbon Nanotubes (MWCNTs), carbon nanospheres (CNs) and Carbon Nanodiamonds (CDs). Carbon nanoparticles have a wide variety of biomedical applications, such as drug delivery, (Girigoswami, K., & Girigoswami, A. (2025). bioimaging, anti- bacterial, anti-viral properties, and cancer therapy, and also wound regeneration, tissue engineering and invitro diagnostics, they show good biocompatibility and solubility.

Green synthesis is more efficient because of 1) Eco-friendly and Reduced Toxicity; its uses natural precursors including plant extracts or microbes which are found to be safer and less polluting. This study reveals that green synthesis of carbon nanostructures is low-cost, and convenient method (Qasim *et al.*, 2023). A study by *Vasimalai et al.*, reports low-toxicity diagnostic and therapeutic pathway for selective tumour cell inhibition (Vasimalai, 2018). Several studies show 2) Low energy consumption and cost is only needed for green synthesis nanoparticles, this study shows the synthesis of Carbon Dots (CDs) from watermelon peel by the NaCl-facilitated carbon dot method, so it reduces more energy consumption than the other chemical methods (Wu and Huang. 2024). A study on bio-mediated synthesis of Carbon Quantum Dots (CQDs) from nutshells for advanced performance in Dye- Sensitised Solar Cells (DSSCs) conveys that using the hydrotherma, microwave-assisted method at a lower temperature below 200 degrees Celsius for a shorter method indicates reduced energy use compared to other chemical synthesis (Yu *et al.*, 2025). 3) High scalability This study introduced a scalable, green -synthesised single-step method for synthesising carbon nanotubes with high catalytic performance (Gang *et al.*, 2023). 4) Biocompatible surface A study reports that carbon dots synthesised from a natural plant called *Pollen Typhae* (PT-CDs) exhibit a high biocompatible surface due to their low cytotoxicity which shows low haemolysis rate, and exhibit high cell biocompatibility. And PT-CDs exhibited no nephrotoxic

DOI: 10.5530/pres.20260128

effects toxicity in the kidney biochemical parameters; this makes carbon dots from PT-CDs suitable for biomedical use.

This review highlights that the green synthesis of carbon nanoparticles from biomass act as more eco- friendly, highly scalable and low in cytotoxicity than other methods. In this review we discuss the various methods of green synthesis and types of carbon nanoparticles. In addition, we described the application and types of carbon nanoparticles on wound healing (Figure 1).

METHODS OF GREEN SYNTHESIS OF CARBON NANOPARTICLES

Carbon Dots (CDs), Carbon Quantum Dots (CDQs), fullerene (C_{60} A study shows bio-mediated synthesis of carbon dots from *Buchnania lanzan* leaf extracts through 1) **Solvothermal treatment** shows good fluorescent property; the Fourier Transform Infrared spectroscopy (FTIR) spectrum indicates the existance of functional groups on the surface acts as stable scaffold for drug delivery and bio imaging (Jana and Dev, 2021). A study exhibits the preparations of high quantum efficiency of green fluorescent Carbon Dots (CDs) by using a simple **2) Hydrothermal technique** with excellent pH and salt stability, and this study claims that these CDs are applicable for fingerprint detection and selective probes for Fe+ detection in environmental and biological systems (Li *et al*., 2019). In a study exhibiting green **3) Microwave assisted method** used for green synthesis of Carbon Quantum Dots (CQDs) from *Viburnum opulus* fruit extracts results in high fluorescence, good water solubility, and biocompatibility, and it aims to be applicable in bioimaging and environmental sensing (Dayan, 2019) (Thirumalai, A. *et al* 2025). A study shows that Carbon Quantum Dots (CQDs) synthesized from silk fibroin through micro -assisted method exhibit high crystallinity, strong fluorescence, low toxicity and high biocompatibility, promising that they are applicable in biomedical applications, bioimaging and drug delivery (Wang *et al*., 2020). In a study the green synthesis of Carbon Dots (CDs) from cellulose and lignin through the solvent-free **4) Pyrolysis method** and its very excellent selectivity in Fe^+ ion detection, so they claim that these Carbon Dots (CDs) are a potential indicator for environmental sensing applications (Chen *et al*., 2022). In a study, green synthesized Carbon Quantum Dots (CQDs) from neem bark powder via **5) Ultrasonification** exhibit strong fluorescence and water dispersibility and show high methylene blue removal capacity (Basha *et al*., 2024). This study outlines green synthesized Carbon Quantum Dots (CDQs) using hydrogen peroxide (H_2O_2) assisted **6) Hydrothermal Oxidation** (Chemical Oxidation) from nutshell biomass. The product of 3 nm CDQs shows strong fluorescence, water stability and functional surface properties (Yu *et al*., 2025). This study demonstrates the green synthesis of nitrogen and sulfur co -doped Carbon Quantum Dots (CDQs) from lignin using **7) Chemical Oxidation** which shows high fluorescence, water solubility, and it is applicable for bioimaging (Zhu *et al*., 2021). In this study *et al* demonstrates the green synthesis of Carbon Nanotubes (CNTs) from the plant extracts (Neem, Walnut and Rose grass) using **8) Chemical Vapour Deposition (CVD)**. It exhibits low toxicity, reduces energy consumption through this method, and yields high purity (CNTs) (Tripathi *et al*., 2017). A study exhibits the synthesis of hollow Carbon Nanospheres (CNs) by **9) Arc Discharge method** utilising copper as both a catalyst and a transient template, resulting the nucleation of carbon on the copper surface with high crystallinity, scalability and biomedical applications in drug delivery systems (Hu *et al*., 2016). This study demonstrates that green synthesized carbon microstructures from biomass using femtosecond **10) Laser Ablation** result in good porosity, conductivity and thermal stability, and they are suitable for applications in sensors, electro catalysis, environmental monitoring (Tavangar *et al*., 2013). A study exhibits the carbon nanofibers synthesized using lignin with Polyvinyl Alcohol (PVA) through **11) ElectroSpinning** followed by **Stabilisation and Carbonisation** This yields porous, conductive and thermally stable CNFs show high surface area and mechanical integrity (Kumar *et al*., 2019). This study demonstrates that bio-mediated synthesis of nanoporous carbon using plant stems of *Ipomoea Carnea* and a nickel foam template. **12) (Template Assisted Growth)** followed by thermal carbonization at 800°C after chemical activation steps results in extensive surface area, tiny pores, and advanced performance in super capacitors with nonporous carbon (Kumaresan *et al*., 2019). A study on the synthesis and characterization of bio-based carbon nanoparticles from lignin applying **13) freeze-drying - induced self-assembly and carbonisation** yields uniform particle size, non- agglutinated carbon nanoparticles and enhanced porosity (Gonugunta *et al*., 2012).

Carbon Dots

Carbon dots are a class of carbonaceous nanomaterials, possess sizes below 20 nm. Carbon Dots (CDs) are classified into Carbon Nanodots (CNDs), Polymer Carbon Dots (PCDs), and Graphene Quantum Dots (GQDs) (Liu *et al*., 2015). Carbon Nanodots (CNDs) are carbonaceous particles with crystal lattice and without crystal lattice are called Graphene Quantum Dots (GQDs) contain a single layer of carbon core conjugated with different chemical groups at the surface. In this demonstrates that the production of **carbon dots** from six medicinal plants exhibits strong antioxidant properties and low toxicity leading to great potential in future biomedical applications (Nascimento *et al*., 2024). This study demonstrates Carbon Quantum Dots (CQDs) from waste nutshell bio-mass using hydrothermal approach with hydrogen peroxide (Yu *et al*., 2025). This study represents the green synthesis of Carbon Quantum Dots (CQDs) from waste lignocellulostic pulp, shows potent fluorescence, antioxidant and antibacterial properties (Lee, and Ko, 2025).

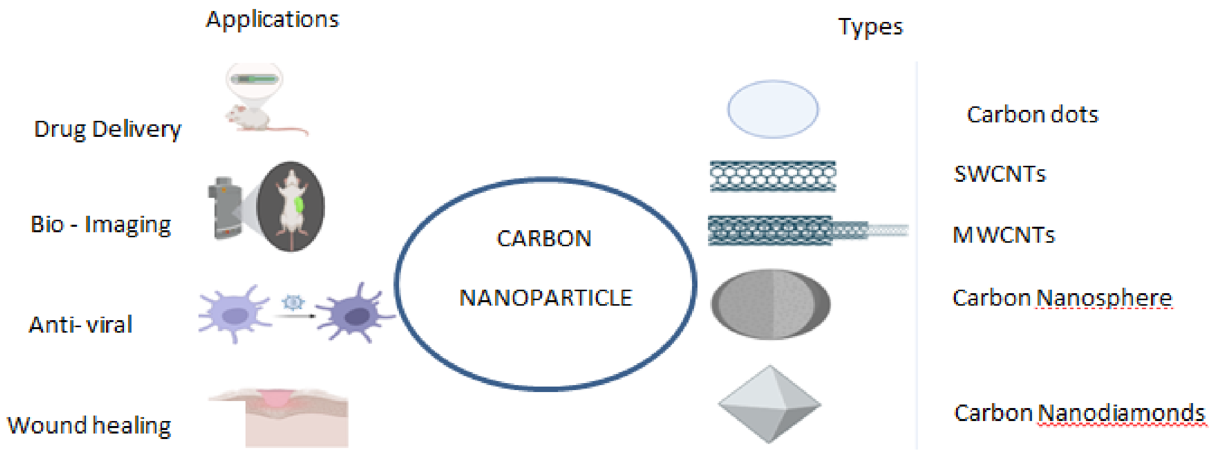

Figure 1: Types of Carbon nanoparticles and its applications.

Therapeutic application of Carbon Dots

This study develops a nanodrug delivery system using carbon dots that shows high therapeutic efficiency, HER_2- el targeted specificity and pH- triggered release with the chemotherapeutic drug Docetaxel (DTX) (Li *et al*., 2021). This study establish green synthesized Carbon Quantum Dots and their silver composite structure. Mishra *et al*., tested on HCT-116 colorectal cancer cells with CQD/Ag nanocomposites and established anti-cancer effects through Reactive Oxygen Species (ROS) mediated mitochondrial apoptosis. The CQD/Ag nanocomposites work as both an anticancer agent and bioimaging probe, leading to new directions for nanotechnology (Mishra *et al*., 2023). Wang *et al*., demonstrate green synthesized Carbon Dots (CDs) <10 nm through *in vitro* and *in vivo*, cell line studies exhibit strong anti-inflammatory and anti-oxidant properties through suppressing ROS, interfering with lipid peroxidation, conserving mitochondrial function inhibiting stress-induced apoptosis and stabilize normal cellular functions (Wang *et al*., 2023). This study presents green synthesized carbon dots from Traditional Chinese Medicinal sources (TCM), *Rubia cordifolia* L., *Junci medulla carbonisata, Cirsium setosum* using the hydrothermal method. Through *in vivo* models they promised the anti-inflammatory protection and promote hemostasis and low cytotoxicity, leading to non-toxic nanotechnology therapeutic system in future (Han *et al*., 2023). In this study demonstrates green synthesized carbon dots from silkworm cocoon by hydrothermal method targeted to accelerate of hemostasis, promote cellular repair and tissue regeneration by platelet aggregration, induce fibrin formation, and reduce Prothrombin Time (PT) and Activated Prothrombin Time (APT) using an animal model .They revealed SC-CDs, silk worm cocoon-derived Carbon Dots (CDs), elevate fibroblast regeneration and increase collagen deposition, anti-inflammatory properties and show less toxicity (Wu *et al*., 2025).

Carbon Nanotubes (Cnts)

Carbon nanotubes are cylindrical nanostructure from hexagonal carbon lattices exhibit a helical twist around the tube axis. Carbon nanotubes are classified into two depending upon the presence of layer: Single Walled Carbon Nanotubes (SWCNTs), Multi Walled Carbon Nanotubes (MWCNTs), and other types (Torodial Carbon Nanotubes (TCNTs), Helical Carbon Nanotubes (HCNTs), Bamboo Carbon Nanotubes (BCNTs) (Zhao *et al*., 2023). In SWCNTs there is a single layer graphene that is folded to produce a tubular structure. In MWCNTs there is three to five sheets of SWCNTs folded up together to form a multi-layer structure (Singh *et al*., 2016). In this study Alhajiri *et al*., demonstrates the green synthesized Silver functionalized MWCNTs using *Olea europea* (Olive) leaf extracts. This MWCNT-Ag nanocomposite shows strong antibacterial properties and low cytotoxicity. It has potential application in

Drug delivery, wound healing and biosensors (Alhajri *et al.,* 2022). In a study Sasrimuang *et al.,* presented green synthesized Carbon Nanotubes (CNTs) using Water Hyacinth through Chemical Vapor Deposition (CVD). This study aims to demonstrate the green synthesis of nanoparticles through eco-friendly transformation of bio-Waste mass. Water hyacinth consists of alumina and silica, so there is no need for the use of metal catalyst during the process (Sasrimuang *et al*., 2020). Kumar *et al*., synthesized aligned CNTs bundles using neem oil (*Azadirachta indica*) via spray pyrolysis (Kumar *et al*., 2011). This study demonstrates the green synthesis of MWCNTs from methyl ester of *moringa (Moringa oleifera)* oil through CVD. Further supporting a study shows the potential of plant -based oil in the development of nanomaterials (Kalaiselvan *et al*., 2018). In this study demonstrates that the PEG - functionalized Single-Walled Carbon Nanotubes (SWCNTs) are efficiently used for both non -invasive tumor imaging and photothermal cancer therapy. The PEG- SWCNTs aqueous water solubility, biocompatibility and cytotoxicity effects and excellent biocompatibility (Singh *et al*., 2024).

Biomedical application of Carbon nanotubes

In this study *Unai et al.,* developed a green synthesized nanocomposite: Hydroxyapatite (HAP), MWCNTs and silver doped with silver core selenium shell configuration Anti-microbial nanoparticle this Nano composite shows strong antimicrobial activity and comparing the three nanocomposites HAP and HAP/MWCNT didn't exhibited any anti-microbial properties, while Ag-HAP/MWCNT demonstrates an intermediate anti- bacterial effect and Ag@ Se HAP /MWCNT Nanocomposites manifest a high potential antibacterial effect (Unai *et al*., 2025). In another study silver -substituted hydroxyapatite functionalized MWCNTs nanocomposites (Ag-HA/f-MWCNTs) developed on 316L stainless steel by spray pyrolysis this study result showed Ag-HA/f-MWCNTs nanocomposites possess high potential antimicrobial property, high cytocompatibility, blood compatibility and enhanced anticorrosive properties. Ag-HA/fMWCNTs coating surfaces provide a versatile surface for dental and orthopedic fields (Sivaraj *et al*., 2019). This study demonstrates that the green -synthesized MWCNTs functionalized Ag-NPs possess enhanced antibacterial property and reduced cytotoxicity and can be used for therapeutic applications including anti- septic biomaterials, topical wound treatment (Seo *et al*., 2018). You *et al*., developed MWCNT-AST and MWCNT-Ag nanocomposite with *astaxanthin* (AST) exhibits enhanced antioxidant activity and strong anti- biofilm activity. They revealed MWCNTAST shows potent anticancer activity in MDA-MB - 23 breast cancer cells with MWCNT-AST-10 shows lower cytotoxicity than MWCNT-Ag (You *et al*., 2025) (Biswas, K. *et al* 2025).

Carbon Nanospheres (CNS)

The study demonstrates green one-step hydrothermal approach to synthesize **Carbon Nanospheres (CNs)** from bacterial cellulose, with potential application in cancer -targeted drug delivery. In this study here Doxorubicin (DOX)- loaded CNs showing minimal drug release in normal tissue and accelerated release in the tumor environment. This approach enhances healing potential against cancer cells and reducing side effects on healthy cells (Robinson *et al*., 2010). Carbon nanospheres (CNs) are spherical in shapes, composed of carbon material. In a study, Nieto-Márquez *et al*., classified CNs into three according to their structural features: concentric, radial, randomly oriented carbon layers (Márquez *et al*., 2011). *Han, et al*., synthesized nitrogen doped Hollow Core- Mesoporous Shell Carbonaceous Nanaospheres (HCDMSs) from Glucosamine Hydrochloric Acid (GAH) carbohydrate derivative, showing high specific surface area, sufficient nitrogen content, adaptable shell thickness and size (Han *et al*., 2014). The study reported the synthesis of blue -fluorescent Carbon Nanospheres (CNs) from the pith of tapioca *(Manihot esculenta)* via a one- step hydrothermal process exhibiting high detection sensitivity (Nima *et al*., 2020). Similarly, Chopra *et al*., presents green synthesized Carbon Nanospheres (CNs) from banana peels through microwave -assisted method and revealed this Carbon Nanospheres (CNs)produced in acidic environment were uniform and shows potent solubility and photostability (Chopra *et al*., 2024). Bhavya krishnappa *et al*., developed green synthesized carbon nanospheres (CNs) from Oil Palm Leaves (OPL) biowaste through a pyrolysis process, resulting uniform -sized carbon nanospheres with excellent colloidal stability, recyclability and high adsor[ption capacity (Krishnappa, *et al*., 2022). In this study synthesized **Mesoporous Carbon Nanoparticle (MCNs)** using hard template method for the delivery of anticancer drugs (Camptothecin). These MCNs exhibits sustained controlled release, efficient intracellular uptake, and prolonged drug release, for targeted cancer therapy (Liu *et al*., 2015). Another study developed the green synthesis of **Mesoporous Carbon Nanospheres (MCNs)** from agro-waste through a **onepot pyrolysis method.** These MCNs were effective against gram -negative bacteria, making them antimicrobial nanomaterials applicable in biomedical and health fields. Long chen *et al*., developed mesoporous carbon nanocomposites using cotton fabric and iron nitrate as precursors via an impregnation - carbonization process *(Chen et al., 2016*). This study presents hydrophilic MCNs through templating and hydrothermal processes, which demonstrates high potent in drug- loading capacity for camptothecin (Gu *et al*., 2011). Futhermore the synthesis of mesoporous Carbon/Copper Sulfide (CUS) nanocomposites using hard-template hydrothermal method obtained (MCN-CUS) mesoporous carbon capped with copper sulfide, showed high potent in drug -loading capacity for Doxorubicin (DOX) and exhibited potent Near-Infrared (NIR) absorbance is applicable for the photothermal treatments (Zhang *et al*., 2015).

Biomedical application of Carbon nanospheres

Manaf *et al*., successfully developed carbon nanospheres from sago hampas through catalyst- free pyrolysis resulting biocompatible, high colloidal stability, uniform sized nanoparticle suggesting for bio imaging, drug delivery and biosensing (Manaf *et al*., 2015). In another study, Sulphur -and nitrogen-co-doped carbon Nanospheres were synthesized from *Hibiscus sabdariffa L.* flower extract via a hydrothermal method. The resulting uniform-sized carbon nanospheres exhibited enhanced hydrophilicity. Hussain *et al*., reported this as a nature corrigendum to green synthesis of Sulphur- and nitrogen- co-doped carbon nanospheres and their application as efficient adsorbent for Pb (II) ions from aqueous solution due to the presence of sulphur and nitrogen (Hussain *et al*., 2020).

Nano-Diamonds (NDs)

Nanodiamonds (NDs) are sp3 -bonded and tetrahedral bonded to four substituent groups like OH, C=O, CH_2/CH_3 (Gopinath *et al*., 2022). A study developed carbon nanodiamonds in under low temperature by the microplasma induced dissociation of ethanol vapour. And hydrogenation phase leads to purification and removes non -diamond carbon and stabilized nanodiamonds results high quality 2-3 nm ultra small nanodiamonds (Kumar *et al*., 2013). A study demonstrated NDs can be incorporated with living microorganisms (Paramecium caudatum and Tetrahymena thermophilia) can be used as consistent intracellular probes. They studied both 5 nm and 100 nm NDs, the smaller 5 nm showed higher toxicity when compared to 100 nm NDs due to their defective surface carbon. Through fluorescence and dynamic scattering imaging proved that NDs have stable fluorescence signal in intracellular without photobleaching making them as suitable long -term bioimaging and their properties like biocompatibility and low cytotoxicity suggests that NDs exhibit high potential as bio- labels, drug delivery systems in biomedical applications (Lin *et al*., 2012). This study developed carbon Nanodiamonds (NDs) using the biopolymer butanosolvent lignin through the pyrolysis method (Feng *et al*., 2024). Lin *et al*., demonstrated Nanodiamonds (NDs) from biomass - derived carbon films using a nanolignin /cellulose nanofibril (LCNF) composite, resulted in uniform sized carbon Nanodiamonds (NDs) (Lin *et al*., 2021). This study reported the carbon Nanodiamonds (NDs) from ethanol through laser irradiation, resulting stable Nanodiamonds (NDs) crystals (Nee *et al*., 2016). Another study developed carbon nanodiamonds via a liquid - phase plasma process using ethanol, which resulting eco-friendly, high scalable uniformly sized, and crystalline nature carbon Nanodiamonds (NDs). Figure 2 illustrates the green synthesis of carbon nanoparticle and its application on wound healing.

wound healing and carbon nanoparticle

Yu *et al*., successfully synthesized carbon dots from sucrose, glucose, and fructose via green wet chemical method exhibited strong antibacterial properties with enhanced wound healing, providing an effective approach for topical therapies in wound management (Yu *et al*., 2025). Roy *et al*., reveals the green synthesis of (ZN-Cur CDs) Curcumin - derived carbon dots doped with zinc ions via photochemical method. These carbon dots showed potent antimicrobial photodynamic activity by producing Reactive Oxygen Species (ROS). It promoted tissue regeneration, enhanced angiogenesis and collagen formation achieved faster wound closure with superior tissue repair, highlighting its future applications in clinical wound care (Roy *et al*., 2024). This study synthesized resveratol -derived carbon dots via a one pot green synthesis method using resveratol with citric acid. They exhibit low cytotoxicity (up to 200 μg/mL), significantly enhanced cell proliferation migration, accelerated in vivo wound contraction, and achieved complete healing by day 14. Histological analysis reported enhanced repair, angiogenesis, re-epithelization and collagen deposition ensures their safety and it's is applicable for biomedical implementations. In a study demonstrated the green synthesized nanoparticle through a single-step microwave -assisted approach using six medicinal plants showed excellent

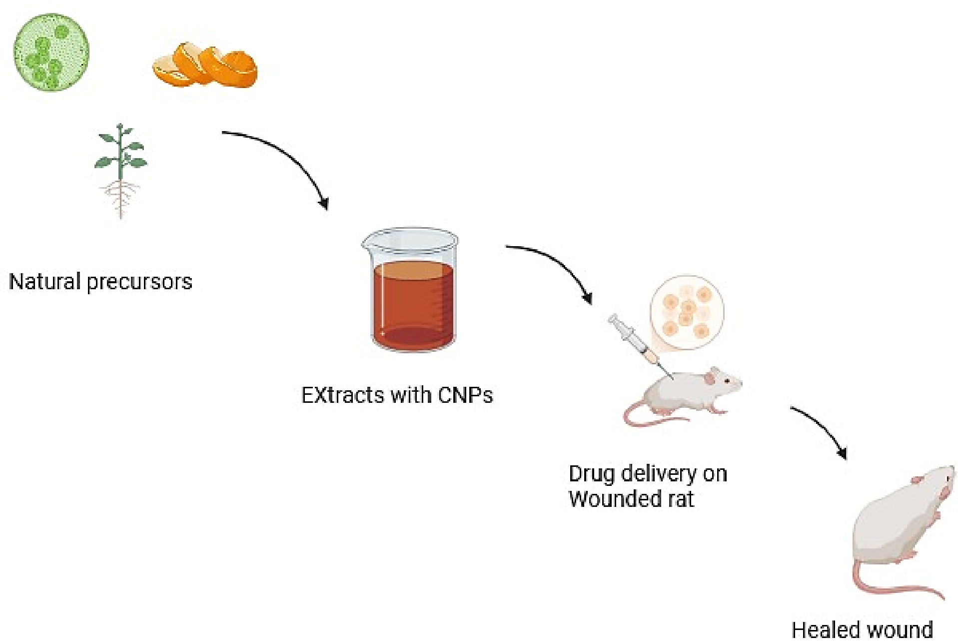

Figure 2: Green synthesis of CNPs and its application on wound healing.

DPPH activity across tested concentrations, suggesting anti -oxidants capacity to mitigate oxidative stress, and potential for integration into topical formulations or wound dressings (Singh *et al*., 2024). The study synthesized the green synthesis of carbon dots from Bovine Serum Albumin (BSA) using a hydrothermal method resulting carbon dots showed high biocompatibility, low cytotoxicity and prospective antibacterial effects against wound pathogens including *Streptococcus pyrogens, Staphylococcus aureus*, and MRSA they demonstrates that when this carbon dots conjugated with antibiotic linezolid, they stimulated migration and proliferation and enhancing wound healing applications (Ghataty *et al*., 2023). This study reported carbon dots from resveratol and citric acid through one pot hydrothermal method results potent biocompatibility, antimicrobial and antioxidant properties. *In vivo* studies showed the promotion of wound healing through cell propagation, migration and angiogenesis, resulting as a novel wound healing application (Cheng *et al*., 2023). Thu *et al*., demonstrated CQDs/AgNPs composite from chitosan showed a synergistic antibacterial effect against the carbapenem - resistant Acinetobacter baumannii (Thu *et al*., 2023). This study developed curcumin loaded carbon nanospheres integrated with polyvinyl alcohol nanofibers derived from sandal wood bark via pyrolysis and electrospinning. The nanofibers fabrication showed excellent wound healing properties through its anti- microbial property. The synergistic effect of curcumin with PVA nanofiber, increase regeneration of wound tissue and potent wound healing efficacy and applicable for bio-based dressing as a novel therapeutic application. In another study (Biswal *et al*., 2023), fabricated chitosan films incorporated with f-MWCNT and nanotitania using concentrated nitric acid exhibited potent wound healing in both Drosophilia and rat models. Antibacterial assays confirmed antibiofilm activity compared to chitosan plate these findings promise the (CS/PVA@TiO2 /f-MWCNT) is effective for wound healing applications (Biswal *et al*., 2023). This study developed carbon nanoparticle from *Piper longum*, which exhibited potent antibacterial and antibiotic activity (Janaranjani *et al*., 2024). Shandilya *et al*., developed Biofib Gel using green -synthesized *Curcuma longa* -reduced Silver Nanoparticles (AgNPs) (1%) with 1% Carbon Dots (CDs). This solution demonstrated high water absorption capacity, anti-microbial activity, collagen deposition, fibroblast proliferation and tissue regeneration making it to advanced wound healing activity (Shandilya *et al*., 2021). A study developed Carbon Nanospheres (CNs) from Oil Palm Leaves (OPL) through pyrolysis loaded with curcumin, and integrated with chitosan membranes, The resulting CNs exhibited enhanced moisture -absorbing property, anti- bacterial activity-This synergistic effect of Carbon Nanosphere (CNs) and the chitosan scaffold accelerate tissue regeneration and wound healing. Overall, the green synthesis Carbon Nanosphere (CNs) -chitosan scaffold is suitable and effective for wound dressing applications (Velmurugan *et al*., 2022). This study developed silver-incorporated mesoporous carbon Nanoparticles (MCNs), resulting advanced and promising tool for wound healing process in both acute and chronic wounds (Torre *et al*., 2019). Bhatt *et*

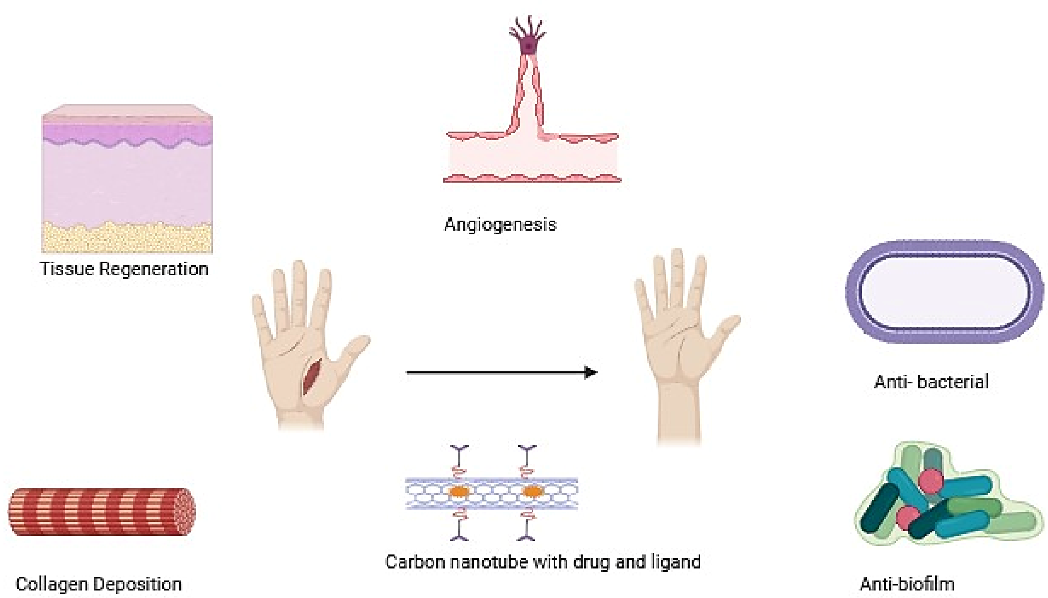

Figure 3: Drug loaded carbon nanoparticle and its properties on wound healing.

al., demonstrated Mesoporous Carbon Nanospheres (MCNs) derived from onion peel via pyrolysis. Toxicological profiling in animal model *Drosophilia melanogaster* for confirmed their non -toxic nature (Bhat *et al*., 2022). Drug loaded Carbon Nanotubes (CNTs) and their roles in tissue repair (Figure 3).

CONCLUSION

Biomass providing carbon reservoir, can be utilized for the green - synthesis of CNPs, providing eco-friendly, low cost, high scalable when comparing to chemical and physical synthesis. Biomass such as fruit peels, leaves extracts are excellent source for carbon are utilized to develop diverse varieties of CNPs such as (CDs, CNTs, CNSs, NDs) have been shown sustainable potential for biomedical fields. In Particular they play a crucial role in wound healing by enhancing cell propagation, migration and angiogenesis. However, the scalability and incorporation of carbon nanodiamonds in wound healing application is still limited. This review summarizes the simple production of CNPs and their roles in biomedical application, bridging them to advanced approaches in wound healing.

ACKNOWLEDGEMENT

We extend our sincere gratitude to Saveetha Medical College and Hospital for providing a platform to express our knowledge

ABBREVIATIONS

APT: Activated Prothrombin Time; **AST**: Astaxanthin; **BCNTs:** Bamboo Carbon Nanotubes; **BSA:** Bovine Serum Albumin; **CDQs:** Carbon Quantum Dots; **CDs:** Carbon Dots; **CNDs:** Carbon Nanodots; **CNPs:** Carbon Nanoparticles; **CNs:** Carbon Nanospheres;**CNTs:** Carbon Nanotubes; **CQDs:** Carbon Quantum Dots; **CUS:** Copper Sulfide; **CVD:** Chemical Vapor Deposition; **DOX**: Doxorubicin; **DSSCs:** Dye-Sensitised Solar Cells; **DTX:** Docetaxel; **FTIR:** Fourier Transform Infrared Spectroscopy; **GAH:** Glucosamine Hydrochloric Acid; **GQDs:** Graphene Quantum Dots; **H_2O_2:** Hydrogen Peroxide; **HAP:** Hydroxyapatite; **LCNF:** Nanolignin /Cellulose Nanofibrile; **MCNs:** Mesoporous Carbon Nanoparticles; **MRSA:** Methicillin-Resistant *Staphylococcus aureus*; **MWCNTs:** Multi-Walled Carbon Nanotubes; **NDs:** Nanodiamonds; **NIR:** Near-Infrared; **OPL:** Oil Palm Leaves; **PCDs:** Polymer Carbon Dots; **PT:** Prothrombin Time; **PVA:** Polyvinyl Alcohol; **ROS:** Reactive Oxygen Species; **SC-CDs:** Silk Worm Cocoon-Derived Carbon Dots; **SWCNTs:** Single-Walled Carbon Nanotubes; **TCM:** Traditional Chinese Medicinal Sources; **TCNTs:** Torodial Carbon Nanotubes; HCNTs: Helical Carbon Nanotubes; **ZN-Cur CDs:** Curcumin-Derived Carbon Dots doped with Zinc Ions.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Mrs Steffy Dominic- Literature research, manuscript writing

Dr. Rajeshkumar Shanmugham, Dr. Elumalai perumal - Study Design, manuscript correction

SUMMARY

This review integrates the green synthesis of Carbon Nanoparticle (CNPs) through sustainable eco-friendly synthesis routes revealing not only minimize the ecological effect but also produce nanomaterials in high biocompatibility and less toxicity. Biomedical assessments indicated their remarkable therapeutic potential such as antioxidant, anti-inflammatory, cancer therapy and wound healing. Overall, the synthesis, biomedical applications, integrating multi- functional composites mark a significant pathway towards eco- sustainable and translational nanomedicine for the novel-wound healing applications.

REFERENCES

2 spike protein: electrochemical impedance immunosensing on a gold microelectrode. Mikrochimica Acta, 189(6). https://doi.org/10.1007/s00604-022-05320-7

Agsubstitutehydroxyapatite/functionalized multiwall carbon nanotube nanocomposite coating on 316L stainless steel for biomedical application. Ultrasonics Sonochemistry, 59, 104730.

Alhajri, H. M., Aloqaili, S. S., Alterary, S. S., Alqathama, A., Abdalla, A. N., Alzhrani, R. M., and Alsaab, H. O. (2022). Olive leaf extracts for a green synthesis of silver-functionalized multi-walled carbon nanotubes. Journal of Functional Biomaterials, 13(4), 224.

Biswas, K., Mercy, D. J., Girigoswami, A., & Girigoswami, K. (2025). Exploring the inhibitory potentials of metal-doped graphene in combating biofilm formation: a review. Zeitschrift für Naturforschung C, (0)

Bhat, V. S., Kudva, A. K., Naik, H. V., G, R., Raghu, S. V., De Padova, P., and Hegde, G. (2022). Toxicological profiling of onion-peel-derived mesoporous carbon nanospheres using in vivo *Drosophila melanogaster* model. *Applied Sciences*, *12*(3), 1528.

Biswal, A., Purohit, S. S., Pratapsingh, J., Mishra, L., Mishra, M., Biswal, S. B., and Swain, S. K. (2023). Synergistic Effects of f-MWCNTs and Nano Titania on the Wound Healing Efficacy of Chitosan Films in Drosophila and Rat Models. *ACS Applied Nano Materials*, *6*(24), 23064-23077.

Chen, L., Ji, T., Mu, L., Shi, Y., Brisbin, L., Guo, Z., and Zhu, J. (2016). Facile synthesis of mesoporous carbon nanocomposites from natural biomass for efficient dye adsorption and selective heavy metal removal. *Rsc Advances*, *6*(3), 2259-2269.

Chen, M., Zhai, J., An, Y., Li, Y., Zheng, Y., Tian, H., and Lin, X. (2022). Solvent-free pyrolysis strategy for the preparation of biomass carbon dots for the selective detection of Fe3+ ions. *Frontiers in Chemistry*, *10*, 940398..

Cheng, H., Zhao, Y., Wang, Y., Hou, Y., Zhang, R., Zong, M., and Li, B. (2023). The potential of novel synthesized carbon dots derived resveratrol using one-pot green method in accelerating *in vivo* wound healing. *International Journal of Nanomedicine*, 6813-6828.

Chopra, T., and Parkesh, R. (2024). Microwave-assisted synthesis of functionalized carbon nanospheres using banana peels:pH-dependent synthesis, characterization, and selective sensing applications. *ACS omega*, *9*(4), 45554571.

Damera, D. P., Manimaran, R., Krishna Venuganti, V. V., and Nag, A. (2020). Green synthesis of full-color fluorescent carbon nanoparticles from eucalyptus twigs for sensing the synthetic food colorant and bioimaging. *ACS omega*, *5*(31), 19905-19918.

Dayan, S. (2019, December). Microwave-Assisted and Green Fabrication of Carbon Quantum Dots from *Viburnum opulus* for Potential Bioimaging Applications. In *Proceedings* (Vol. 40, No. 1, p. 11). MDPI.

Do Nascimento, W. C., Ramo, L. B., da Silva, F. F., Araujo, M. C., de Andrade, S. I., and Bichinho, K. M. (2024). One-step microwave-assisted synthesis of fluorescent carbon quantum dots for determination of ascorbic acid

Dutta, V., Verma, R., Gopalkrishnan, C., Yuan, M. H., Batoo, K. M., Jayavel, R., and Ghotekar, S. (2022). Bioinspired synthesis of carbon-based nanomaterials and their potential environmental applications: a state-of-theart review. *Inorganics*, *10*(10), 169..

Feng, Y., Davidson, D. J., Sun, W., Milani, V., Howieson, G. W., Westwood, N. J., and Zhou, W. (2024). Formation of nanodiamonds during pyrolysis of butanosolv lignin. *ACS nano*, *18*(36), 24803-24811.

Fernández,J.M., and Fernández-Argüelles, M. T. (2018). Green synthesis of fluorescent carbon dots from spices for *in vitro* imaging and tumour cell growth inhibition. *Beilstein journal of nanotechnology*, *9*(1), 530-544.

Gang, Y., Pellessier, J., Du, Z., Fang, S., Fang, L., Pan, F., and Li, Y. (2023). Facile and scalable synthesis of metal-and nitrogen-doped carbon nanotubes for efficient electrochemical CO2 reduction. *ACS Sustainable Chemistry and Engineering*, *11*(18), 7231-7243.

Gedda, G., Sankaranarayanan, S. A., Putta, C. L., Gudimella, K. K., Rengan, A. K., and Girma, W. M. (2023). Green synthesis of multi-functional carbon dots from medicinal plant leaves for antimicrobial, antioxidant, and bioimaging applications. *Scientific Reports*, *13*(1), 6371.

Ghataty, D. S., Amer, R. I., Amer, M. A., Abdel Rahman, M. F., and Shamma, R. N. (2023). Green synthesis of highly fluorescent carbon dots from bovine serum albumin for linezolid drug delivery as potential wound healing biomaterial: Bio-synergistic approach, antibacterial activity, and *in vitro* and *ex vivo* evaluation. *Pharmaceutics*, *15*(1), 234.

Girigoswami, K., & Girigoswami, A. (2025). Integration of Data-Driven Techniques in Nanomedicines to Address Diagnosis and Drug Delivery Strategy for Therapy. Biopharmaceutics & Drug Disposition.

Gonugunta, P., Vivekanandhan, S., Mohanty, A. K., and Misra, M. (2012). A study on synthesis and characterization of biobased carbon nanoparticles from lignin. *World Journal of Nano Science and Engineering*, *2*(3), 148-153.

Gopinath, B., Gopinath, B., Zool Hilmi Ismail, and Subramaniam, S. (2022). Nanodiamond conjugated SARS-CoV-

Gu, J., Su, S., Li, Y., He, Q., and Shi, J. (2011). Hydrophilic mesoporous carbon nanoparticles as carriers for sustained release of hydrophobic anti-cancer drugs. *Chemical Communications*, *47*(7), 2101-2103.

Han, B., Shen, L., Xie, H., Huang, Q., Zhao, D., Huang, X., and Li, J. (2023). Synthesis of carbon dots with hemostatic effects using traditional Chinese medicine as a biomass carbon source. *Acs Omega*, *8*(3), 31763183.

Han, C., Wang, S., Wang, J., Li, M., Deng, J., Li, H., and Wang, Y. (2014). Controlled synthesis of sustainable Ndoped hollow core-mesoporous shell carbonaceous nanospheres from biomass. *Nano Research*, *7*(12), 18091819.

https://doi.org/10.1016/j.ultsonch.2019.104730

Hu, R., Ciolan, M. A., Wang, X., and Nagatsu, M. (2016). Copper induced hollow carbon nanospheres by arc discharge method: controlled synthesis and formation mechanism. *Nanotechnology*, *27*(33), 335602.

Hussain, N., Alwan, S., Alshamsi, H., and Sahib, I. (2020). Green Synthesis of Simage1and Nimage1Codoped Carbon Nanospheres and Application as Adsorbent of Pb (II) from Aqueous Solution. *International Journal of Chemical Engineering*, *2020*(1), 9068358.

Jana, P., and Dev, A. (2021). Green synthesis of fluorescent carbon dots through solvothermal treatment of Buchnania lanzan leaf extract. *Chemistry Proceedings*, *8*(1), 59.

Janaranjani, S., Madhanasundareswari, K., and Raja, K. (2024). Formulation of wound healing hydrogel using carbon nanoparticles synthesized from Piper longum. *Asian Journal of Biological and Life Sciences*, *13*(1), 109.

Kalaiselvan, S., Angulakshmi, V. S., Mageswari, S., and Karthikeyan, S. (2018). Carbon nanotubes from plant derived hydrocarbon-an efficient renewable precursor. *J Environ Nanotechnol*, *7*, 41-6.

Khayal, A., Dawane, V., Amin, M. A., Tirth, V., Yadav, V. K., Algahtani, A., and Jeon, B. H. (2021). Advances in the methods for the synthesis of carbon dots and their emerging applications. *Polymers*, *13*(18), 3190.

Krishnappa, B., Bhat, V. S., Ancy, V., Joshi, J. C., S, J. M., Naik, M., and Hegde, G. (2022). Biowaste-derived, highly efficient, reusable carbon nanospheres for speedy removal of organic dyes from aqueous solutions. *Molecules*, *27*(20), 7017.

Kumar, A., Ann Lin, P., Xue, A., Hao, B., Khin Yap, Y., and Sankaran, R. M. (2013). Formation of nanodiamonds at near-ambient conditions via microplasma dissociation of ethanol vapour. *Nature Communications*, *4*(1). https://doi.org/10.1038/ncomms3618

Kumar, M., Hietala, M., and Oksman, K. (2019). Lignin-based electrospun carbon nanofibers. *Frontiers in Materials*, *6*, 62.

Kumar, R., Tiwari, R. S., and Srivastava, O. N. (2011). Scalable synthesis of aligned carbon nanotubes bundles using green natural precursor: neem oil. *Nanoscale research letters*, *6*(1), 92.

Lee, W., and Ko, S. (2025). Synthesis and Characterization of Lignocellulose-Based Carbon Quantum Dots (CQDs) and Their Antimicrobial and Antioxidant Functionalities. *Molecules*, *30*(3), 667.

Li, J., Ma, S., Xiao, X., and Zhao, D. (2019). The Oneimage2Step Preparation of Greenimage3Emissioned Carbon Dots through Hydrothermal Route and Its Application. Journal of Nanomaterials, 2019(1), 8628354.

Li, J., Wang, Y., Xu, C., Yu, Q., Wang, X., Xie, H., and He, Q. (2021). Rapid pH-responsive self-disintegrating nanoassemblies balance tumor accumulation and penetration for enhanced anti-breast cancer therapy. *Acta Biomaterialia*, *134*, 546-558.

Lin, Y., Perevedentseva, E., Tsai, L., Wu, K., and Cheng, C. (2012). Nanodiamond for intracellular imaging in the microorganisms *in vivo*. *Journal of Biophotonics*, *5*(11-12), 838-847. https://doi.org/10.1002/jbio.201200088

Lin, Y., Zhang, Q. J., Deng, Y. J., Shen, K. Z., Xu, K. M., Yu, Y. C., ... and Fang, G. G. (2021). *Fabricating nanodiamonds from biomass by direct laser writing under ambient conditions. Acs Sustain Chem Eng 9: 3112- 3123*

Liu, X., Jiang, H., Ge, W., Wu, C., Chen, D., Li, Q., ... and Wang, X. (2015). Green and facile synthesis of highly biocompatible carbon nanospheres and their pH-responsive delivery of doxorubicin to cancer cells. *RSC Advances*, *5*(23), 17532-17540.

Manaf, S. A. A., Roy, P., Sharma, K. V., Ngaini, Z., Malgras, V., Aldalbahi, A., ... and Hegde, G. (2015). Catalystfree synthesis of carbon nanospheres for potential biomedical applications: waste to wealth approach. *RSC Advances*, *5*(31), 24528-24533.

Mishra, S., Das, K., Chatterjee, S., Sahoo, P., Kundu, S., Pal, M., ... and Ghosh, C. K. (2023). Facile and green synthesis of novel fluorescent carbon quantum dots and their silver heterostructure: An in vitro anticancer activity and imaging on colorectal carcinoma. *ACS omega*, *8*(5), 4566-4577.

Monte-Filho, S. S., Andrade, S. I., Lima, M. B., and Araujo, M. C. (2019). Synthesis of highly fluorescent carbon dots from lemon and onion juices for determination of riboflavin in multivitamin/mineral supplements. *Journal of pharmaceutical analysis*, *9*(3), 209-216.

Nanoporous Carbon from Bio-Weed of Ipomoea carnea Stems for Supercapacitor Applications. *Asian Journal of Chemistry*, *31*(5), 1163-1168. https://doi.org/10.14233/ajchem.2019.21912

Nee, C. H., Yap, S. L., Tou, T. Y., Chang, H. C., and Yap, S. S. (2016). Direct synthesis of nanodiamonds by femtosecond laser irradiation of ethanol. *Scientific Reports*, *6*(1), 33966.

Nieto-Márquez, A., Romero, R., Romero, A., and Valverde, J. L. (2011). Carbon nanospheres: synthesis, physicochemical properties and applications. *Journal of Materials chemistry*, *21*(6), 1664-1672.

Nima, A. M., Amritha, P., Lalan, V., and Subodh, G. (2020). Green synthesis of blue-fluorescent carbon nanospheres from the pith of tapioca (Manihot esculenta) stem for Fe (III) detection. *Journal of Materials Science: Materials in Electronics*, *31*(23), 21767-21778.

Qasim,M.,Clarkson,A. N., and Hinkley,S.F.R .(2023). Green synthesis of carbon Nanoparticles (CNPs) from Biomass for Biomedical Applications. *International journal of Molecular*

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

Robinson, J. T., Welsher, K., Tabakman, S. M., Sherlock, S. P., Wang, H., Luong, R., and Dai, H. (2010). High performance in vivo near-IR (> 1 μm) imaging and photothermal cancer therapy with carbon nanotubes. *Nano research*, *3*(11), 779-793.

Roy, A. K., Ghann, W., Rabi, S., Barua, J., Majumder, S., Amin, R., ... and Uddin, J. (2024). Hydrogen peroxide assisted synthesis of fluorescent carbon nanoparticles from teak leaves for dye-sensitized solar cells. *RSC Sustainability*, *2*(4), 1003-1013.

Sasrimuang, S., Chuchuen, O., and Marjang, A. (2020). Green Synthesis and Characterization of Carbon Nanotubes from Water Hyacinth Via Chemical Vapor Deposition. *Engineering and Technology Horizons*, *37*(3), 28-33.

Sciences,24(2),1023.https://doi.org/10.3390/ijms24021023.

Seo, Y., Park, C., Son, J., Lee, K., Hwang, J., Jo, Y., ... and Choi, J. (2018). Synthesis of multi-walled carbon nanotubes modified with silver nanoparticles and evaluation of their antibacterial activities and cytotoxic properties. *Journal of Visualized Experiments: JoVE*, (135), 57384.

Shandilya, G., Tarwadi, K., Chavan, S., and Vaghela, J. S. (2021). BioFibGel: A Green Nanotechnology Based Wound Dressing. *INDIAN JOURNAL OF PHARMACEUTICAL EDUCATION AND RESEARCH*, *55*(4), 989-995.

Singh, B., Lohan, S., Sandhu, P. S., Jain, A., and Mehta, S. K. (2016). Functionalized carbon nanotubes and their promising applications in therapeutics and diagnostics. In *Nanobiomaterials in Medical Imaging* (pp. 455-478). William Andrew Publishing.

Singh, P., Dan, A., Kannan, P. P., Dhanka, M., Bhatia, D., and Saha, J. (2024). Non-toxic fabrication of fluorescent carbon nanoparticles from medicinal plants/sources with their antioxidant assay. *arXiv preprint arXiv:2401.10673*.

Sivaraj, D., and Vijayalakshmi, K. (2019). Enhanced antibacterial and corrosion resistance properties of

T.K. Kumaresan, A.M. Shanmugharaj, Raman, K., and Raghu, S. (2019). Template Assisted Synthesis of

Tavangar, A., Tan, B., and Venkatakrishnan, K. (2013). Sustainable approach toward synthesis of green functional carbonaceous 3-D micro/nanostructures from biomass. *Nanoscale Research Letters*, *8*(1), 348.

Thirumalai, A., Durgadevi, P., Kiran, V., Girigoswami, K., Prabhu, A. D., & Girigoswami, A. (2025). Lipid functionalized silver-coated carbon dot-capped manganese ferrite as drug-free core-shell nanoparticles for multimodal imaging and therapy. ADMET and DMPK, 13(5).

Thu, H. T., Anh, L. T., Phuc, L. H., Vinh, L. K., Tung, N. T., and Phuong, P. H. (2023). Green preparation of carbon quantum dots and its silver nanoparticles composite against carbapenem-resistant Acinetobacter baumannii. *Applied Nanoscience*, *13*(6), 4109-4118.

Torre, E., Giasafaki, D., Steriotis, T., Cassinelli, C., Morra, M., Fiorilli, S., ... and Iviglia, G. (2019). Silver decorated mesoporous carbons for the treatment of acute and chronic wounds, in a tissue regeneration context. *International Journal of Nanomedicine*, 10147-10164.

Tripathi, N., Pavelyev, V., and Islam, S. S. (2017). Synthesis of carbon nanotubes using green plant extract as catalyst: unconventional concept and its realization. *Applied Nanoscience*, *7*(8), 557-566.

Unal, İ. (2025). Green Synthesis of Multi-Walled Carbon Nanotube-Reinforced Hydroxyapatite Doped with Silver and Silver-Core Selenium-Shell Nanoparticles: Synthesis, Characterization, and Biological Activity. *Nanomaterials*, *15*(3), 179.

Vasimalai, N., Vilas-Boas, V., Gallo, J., de Fátima Cerqueira, M., Menéndez-Miranda, M., Costa-

Velmurugan, R., Hegde, G., Soontarapa, K., and Keri, R. S. (2022). Evaluation of wound healing effect of curcumin loaded OPL carbon nanospheres embedded chitosan membranes. *Journal of Polymers and the Environment*, *30*(12), 5190-5201.

Wang, Q., Cai, J., Biesold-McGee, G. V., Huang, J., Ng, Y. H., Sun, H., ... and Lin, Z. (2020). Silk fibroin-derived nitrogen-doped carbon quantum dots anchored on TiO2 nanotube arrays for heterogeneous photocatalytic degradation and water splitting. *Nano Energy*, *78*, 105313.

Wang, X., Wu, T., Yang, Y., Zhou, L., Wang, S., Liu, J., ... and Zhang, Y. (2023). Ultrasmall and highly biocompatible carbon dots derived from natural plant with amelioration against acute kidney injury. *Journal of Nanobiotechnology*, *21*(1), 63.

Wang, Y., and Hu, A. (2014). Carbon quantum dots: synthesis, properties and applications. *Journal of Materials Chemistry C*, *2*(34), 6921-6939.

Waseem Basha, Z., Muniraj, S., and Senthil Kumar, A. (2024). Neem biomass derived carbon quantum dots synthesized via one step ultrasonification method for ecofriendly methylene blue dye removal. *Scientific Reports*, *14*(1), 9706.

Wu, J. Y., and Huang, Y. C. (2024). Low-energy-consumption rapid synthesis of carbon dots at room temperature from combusted food waste with versatile analytical applications. *Food Chemistry*, *446*, 138908.

Wu, X., Yao, M., Qiao, X., Li, L., Meng, Z., Liu, S., ... and Dou, G. (2025). Silkworm Cocoon-Derived Carbon Dots for Post-Trauma Hemostasis and Tissue Repair. *Pharmaceuticals*, *18*(5), 603.

You, H.-S., Jang, Y.-S., Anbazhagan Sathiyaseelan, Ryu, S.-J., Lee, H.-Y., and Baek, J.-S. (2025). Antibiofilm and Anticancer Activity of Multi-Walled Carbon Nanotubes Fabricated with Hot-Melt Extruded Astaxanthin-Mediated Synthesized Silver Nanoparticles. *International Journal of Nanomedicine*, *Volume 20*, 343-366. https://doi.org/10.2147/ijn.s485722

Yu, Y., Ouyang, Y., Xu, F., Wang, T., Wei, X., Wang, T., and Yao, Y. (2025). Green synthesis of carbon quantum dots from nutshells for enhanced performance in dye-sensitized solar cells. *RSC advances*, *15*(10), 7938-7947.

Yu, Y., Ouyang, Y., Xu, F., Wang, T., Wei, X., Wang, T., and Yao, Y. (2025). Green synthesis of carbon quantum dots from nutshells for enhanced performance in dye-sensitized solar cells. *RSC advances*, *15*(10), 7938-7947.

Yu, Y., Ouyang, Y., Xu, F., Wang, T., Wei, X., Wang, T., and Yao, Y. (2025). Green synthesis of carbon quantum dots from nutshells for enhanced performance in dye-sensitized solar cells. *RSC advances*, *15*(10), 7938-7947.

Zhang, L., Li, Y., Jin, Z., Chan, K. M., and Yu, J. C. (2015). Mesoporous carbon/CuS nanocomposites for pHdependent drug delivery and near-infrared chemo-photothermal therapy. *Rsc Advances*, *5*(113), 93226-93233.

Zhao, C., Kang, J., Li, Y., Wang, Y., Tang, X., and Jiang, Z. (2023). Carbon-based stimuli-responsive nanomaterials: classification and application. *Cyborg and bionic systems*, *4*, 0022.

Zhu, L., Shen, D., Wang, Q., and Luo, K. H. (2021). Green synthesis of tunable fluorescent carbon quantum dots from lignin and their application in anti-counterfeit printing. *ACS applied materials and interfaces*, *13*(47), 5646556475.

Cite this article: Dominic S, Elumalai P, Shanmugam R. A Review on Green Synthesis of Carbon Nanoparticles and its Biomedical and Wound Healing Applications. Pharmacog Res. 2026;18(4):1103-11.