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# Synthesis of Fluorescent Carbon Dots from Raw Materials: An Overview of Textile Applications

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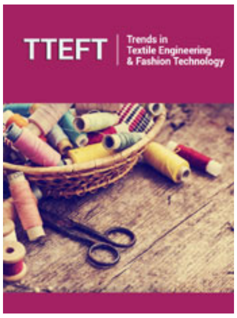


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## Abstract

Since their discovery in 2004, fluorescent carbon dots (C-dots) have been in increasing development with a wide range of applications. Since 2012, the use of carbon sources made from raw materials such as seeds, flowers, and others has increased, and the green synthesis of fluorescent carbon dots has increased. These C-dots have potential in several bioapplications due to their biocompatibility, stability, relatively low cost, biodegradability, nontoxicity, and environmental friendliness. This work discussed C-dot synthesis using different raw materials with different carbon sources and the main synthesis methods. The photophysical parameters of the fluorescence quantum yield ( $\eta$ ) and fluorescent lifetime ( $\tau$ ) are presented for green synthesized nitrogen-doped and undoped C-dots as important nanomaterial for environmental control. These carbon dot-based materials can be used to minimize waste in the textile industry and enhance their waste properties as possible antifungal and bactericidal agents for bioapplications. An overview of the different C-dots used for textile engineering applications and degrading dyes typically used in textile fabrics is presented.

**Keywords:** Carbon dots; Raw materials; Fluorescence quantum efficiency; Fluorescence lifetime; Textile application

## Introduction

Fluorescent carbon nanoparticles or carbon dots (C-dots) were discovered in 2004 during the process of carbon nanotube fragment purification [1-3]. These nanomaterials are widely reported to have average sizes typically smaller than 10nm, are spherical or semispherical in shape, are water soluble, and have fluorescent properties, enabling a wide range of bio applications [4-6]. Carbon dot synthesis has recently attracted increasing attention and interest due to its sustainable synthesis, low toxicity, low cost, and easy implementation [4-7]. These carbon-based nanoparticles have been widely explored, but green syntheses stand out because the raw materials used as carbon sources are components of plants and fruits (such as roots, seeds, leaves, flours, fruit peels, and extracts) and other foods [2,4,8-10]. The first reported green synthesis using coffee grounds as a carbon source occurred in 2012, with C-dots of approximately 5±2nm in size [8]. Several novel C-dots have been proposed using different carbon sources [8,11-22], and this work presents an overview of these carbon dots, the values of their average sizes, fluorescence quantum yield ($\eta$), fluorescence lifetime ($\tau$) values, and high potential for reported textile applications [23-27].

## Discussion

Figure 1 presents the timeline of the main raw carbon sources and methods used in green synthesis from 2012-2024 [8,11-22]. The synthesis C-dots involves hydrothermal, pyrolysis, and microwave methods [11,16,17]. Several carbon sources, such as coffee grounds, sweet pepper, corn flour, *Jinhua Bergamot*, *Lotus* roots, *Acacia Concinna* seeds, *Carica papaya* waste, cherry tomatoes, microalgae *Spirulina*, grapefruit juice, *Naregamia alata* leaves and *Pumpkin* seeds used for C-dot green synthesis are presented in Figure 1. The fluorescence quantum efficiency ($\eta$) and fluorescence lifetime ($\tau$) are given for some C-dots reported in Table 1. A hydrothermal method or heating reaction was used for all the synthesized C-dots, as shown in Table 1. These photophysical characteristics are crucial for fluorescence applications of C-dots.

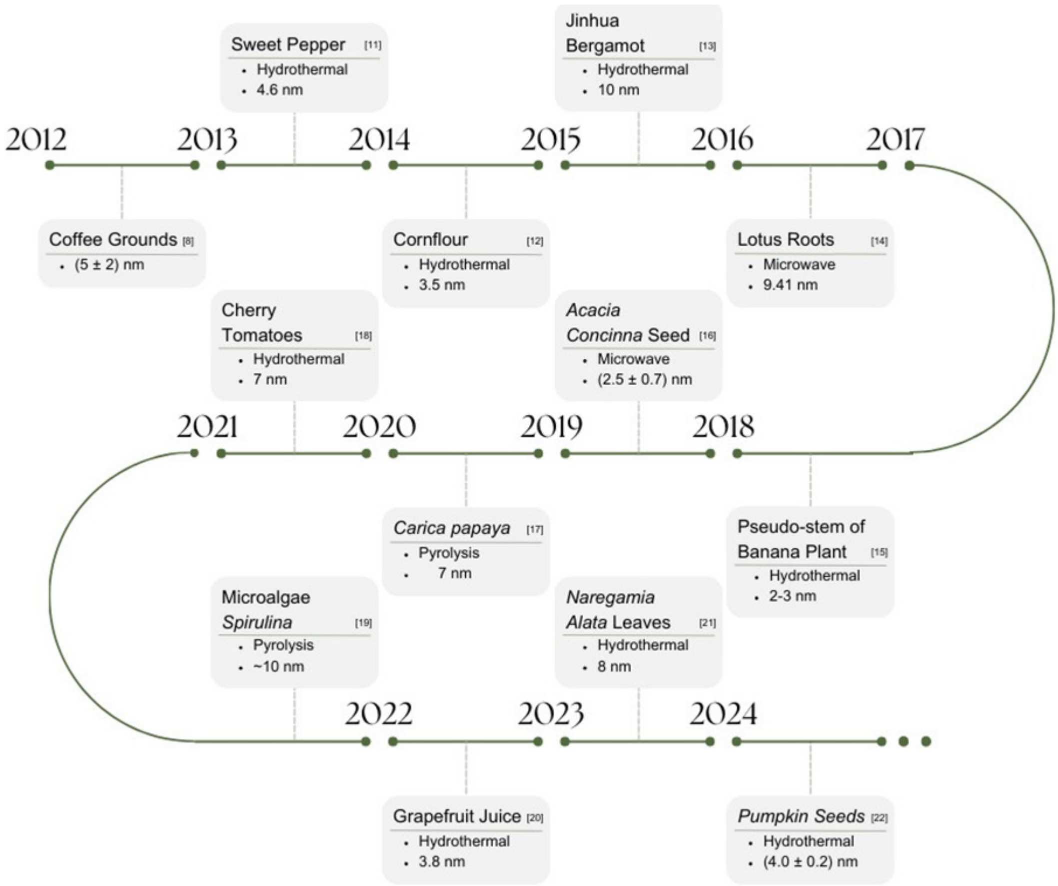


**Figure 1:** Some raw carbon sources and methods used in C-dot green synthesis from 2012-2024 [8,11-22].

**Table 1:** Several carbon sources have been presented for C-dot green hydrothermal or heating reaction synthesis and textile applications. The average sizes of the C-dots and the η and τ parameters are presented.

[a]Average lifetime.

| Carbon Source | Average Size (nm) | η (%) | τ (ns) | Applications |
|---|---|---|---|---|
| Rice straw | (71-101) | 24.03 | 7.55 | Cotton textile mask as a possible fluorescent sensor for detecting acetone vapor in the breath of diabetic patients [23] |
| Indigo | (3.5±0.5) | 3.8 | 3[a] | Textile printing for anti-counterfeiting [24] |
| *Curcuma longa* | (2.6±0.5) | 0.8 | 3.9[a] | |
| *Sophora japonica* L. | (5.2±0.7) | 1 | 1.0[a] | |
| Date fruit (charcoal) | (5±6) | 14.5 | -- | Functional textiles with better UV protection, antibacterial activity, and potential for heavy metal detection [25] |
| *Syzygium cumini* L. seed extract | 6.3 | 15.9 [26] | 5.2 [26] | Biomedical textiles with antimicrobial properties [27] |
| Green tea (Tetley) and chitosan | 6 | -- | -- | Functional textiles with antioxidant and antimicrobial properties for possible smart textiles [28] |

Table 1 presents different C-dots synthesized by the green method and used in textile engineering applications [23-28]. Rice straw was used as a carbon source in nitrogen-doped C-dot synthesis and applied as a fluorescent sensor for acetone detection in cotton in textile masks [23]. The natural dyes extracted from *Curcuma longa* and *Sophora japonica* L. were used in C-dot synthesis and tested as possible textiles for anti-counterfeiting [24]. Other textile applications using C-dots are presented in Table 1. The values obtained for $\eta$ and $\tau$ for rice straw as raw materials highlight the fluorescent sensor textile applications of C-dots.

Table 2 presents different green processes for C-dot synthesis [29-38], such as hydrothermal, pyrolyzed, and calcination processes. These nanodots are potential candidates for detecting


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and degrading dyes typically used in textile fabrics [29,31,32,35-38]. C-dots and N-doped C-dots were synthesized using carbon sources such as peels, seeds, fruits, and leaves. Table 2 presents the average C-dot sizes and fluorescence quantum yield parameters η. For doped C-dots, L-aspartic acid or aqueous ammonia was used for nitrogen doping [36,37], and green synthesis was achieved via hydrothermal processes. N-doped C-dots have been reported to have potential in wastewater analysis for Congo Red dye detection and Safranin-O dye degradation [36,37]. Table 2 presents other C-dot applications for the detection and degradation of dyes.

**Table 2:** The different carbon sources used in green synthesis and the average of the C-dots used in dye removal applications in textiles are presented.

[a]Carica papaya juice was used as a carbon source [30].

[b]C-dots were doped with nitrogen (pyrolysis for 3h) [32].

[c]A hydrothermal method was used, and C-dots with a size of 1nm were obtained [33].

[d]The excitation wavelength was 380nm [34].

| Carbon Source | Synthesis Method | Average Size (nm) | η (%) | Doping Material | Application |
|---|---|---|---|---|---|
| *Canon ball* fruit | Hydrothermal | 11.2 | 7.24 | -- | Sensor for metal ion detection and catalytic reduction of textile dyes [29] |
| Papaya peel | Hydrothermal | 4.5 | 7.0[a] [30] | -- | Nanocomposites were tested for photodegradation of textile dye methylene blue [31] |
| Onion (*Allium cepa*) | Pyrolysis | 4.48[b] [32] | 6.2[c] [33] | Ammonia ($NH_3$) | Decontamination of methylene blue and rhodamine B dyes [32] |
| Olive pomace | Pyrolysis and oxidation | (2.8±0.6) | 19[d] [34] | -- | Photodegradation of methylene blue dye pollutants [35] |
| *Ziziphus mauritiana* fruit | Hydrothermal | (7±2) | -- | Aqueous ammonia | Degradation of Safranin-O dye pollutant [36] |
| Rambutan seed | Hydrothermal | 3.07 | 16.87 | L-aspartic acid | Detection of Congo Red Dye [37] |
| *Azadirachta indica* leaves | Calcination | 3.0-8.0 | 42.3 | -- | Sensing and degradation of Malachite green [38] |

Furthermore, other carbon dots or nanoparticles have been reported in textile applications [39-45]. The carbon quantum dots synthesized by the hydrothermal method can be highlighted by using banana leaves as a carbon source. These nanomaterials are applied for superhydrophobic coating on fabrics for oil and water separation [39]. On the other hand, graphene films integrated with Prussian blue and quantum dots have been reported for textile devices [40]. These proposed advanced films show potential for wearable biosensors and photoelectronic devices, such as glucose and $H_2O_2$ monitoring sensors [40]. Red-emissive carbon dots (R-Cdots) are used to construct smart fabrics. The hydrothermal synthesis of these R-Cdots uses o-phenylenediamine and catechol in ethanol as carbon sources. R-Cdots exhibit fluorescent patterns on cotton fabrics, are pH sensitive, and can be used for $MnO_4$ detection in aqueous solutions [41]. Finally, fabric scraps can also be reused as a carbon source for new carbon dot synthesis, ranging from leather scraps to hospital masks [42-44].

## Conclusion

Since the first green synthesis of carbon dots (C-dots), different carbon sources obtained from seeds, leaves, peels, and other parts of plants have been used in novel synthesis processes. The fluorescence properties, water solubility, and low toxicity are characteristics of carbon dots that stand out for their wide range of applications. C-dots have been used in different applications, such as in printing on textiles to combat counterfeiting and in textiles, highlighting their antioxidant and antimicrobial properties. Another important carbon nanoparticle approach is evaluated for the detection and degradation of dyes commonly used in textile fabrics. Over the years, important new applications of carbon dots have emerged in different research areas of investigation, increasing opportunities for the development of relevant applications in textile engineering.

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## Conflicts of interest

The authors declare that there are no conflicts of interest.

## References

1. Xu X, Ray R, Gu Y, Ploehn HJ, Gearheart L, et al. (2004) Electrophoretic analysis and purification of fluorescent single-walled carbon nanotube fragments. J Am Chem Soc 126(40):12736-12737.
2. Wang H, Su W, Tan M (2020) Endogenous fluorescence carbon dots derived from food items. Innovation 1(1): 100009.
3. Zhou Y, Zhang W, Leblanc RM (2022) Structure-property-activity relationships in carbon dots. J Phys Chem B 126(51): 10777-10796.
4. De B, Karak N (2013) A green and facile approach for the synthesis of water-soluble fluorescent carbon dots from banana juice. RSC Adv 3: 8286-8290.


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5. Jia X, Li J, Wang E (2012) One-pot green synthesis of optically pH-sensitive carbon dots with upconversion luminescence. Nanoscale 4(18): 5572–5575.

6. Himaja AL, Karthik PS, Singh SP (2015) Carbon dots: The newest member of the carbon nanomaterials family. Chem Rec 15(3): 595-615.

7. Zhao S, Lan M, Zhu X, Xue H, Ng TW, et al. (2015) Green synthesis of bifunctional fluorescent carbon dots from garlic for cellular imaging and free radical scavenging. ACS Appl Mater Interfaces 7(31): 17054-17060.

8. Hsu PC, Shih ZY, Lee CH, Chang HT (2012) Synthesis and analytical applications of photoluminescent carbon nanodots. Green Chem 14(4): 917-920.

9. Suvarnaphaet P, Tiwary CS, Wetcharungsri J, Porntheeraphat S, Hoonsawat R, et al. (2016) Blue photoluminescent carbon nanodots from limeade. Mater Sci Eng C Mater Biol Appl 69: 914-921.

10. Salman BI, Hassan AI, Hassan YF, Saraya RE, Batakoushy HA (2023) Rapid one-pot microwave assisted green synthesis nitrogen doped carbon quantum dots as fluorescent precursor for estimation of modafinil as post-covid neurological drug in human plasma with greenmess assessments. J Fluoresc 33: 1101-1110.

11. Yin B, Deng J, Peng X, Long Q, Zhao J, et al. (2013) Green synthesis of carbon dots with down- and up-conversion fluorescent properties for sensitive detection of hypochlorite with a dual-readout assay. Analyst 138(21): 6551-6557.

12. Wei J, Zhang X, Sheng Y, Shen J, Huang P, et al. (2014) Dual functional carbon dots derived from cornflour via a simple one-pot hydrothermal route. Mater Lett 123: 107-111.

13. Yu J, Song N, Zhang YK, Zhong SX, Wang AJ, et al. (2015) Green preparation of carbon dots by Jinhua bergamot for sensitive and selective fluorescent detection of $Hg^{2+}$ and $Fe^{3+}$. Sens. Actuators B Chem 214: 29-35.

14. Gu D, Shang S, Yu Q, Shen J (2016) Green synthesis of nitrogen-doped carbon dots from lotus root for Hg (II) ions detection and cell imaging. Appl Surf Sci 390: 38-42.

15. Vandarkuzhali SAA, Jeyalakshmi V, Sivaraman G, Singaravadivel S, Krishnamurthy KR, et al. (2017) Highly fluorescent carbon dots from pseudo-stem of banana plant: Applications as nanosensor and bio-imaging agents. Sens. Actuators B Chem 252: 894-900.

16. Bhamore JR, Jha S, Park TJ, Kailasa SK (2018) Fluorescence sensing of $Cu^{2+}$ ion and imaging of fungal cell by ultra-small fluorescent carbon dots derived from *Acacia concinna* seeds. Sens Actuators B Chem 277: 47-54.

17. Pooja D, Singh L, Thakur A, Kumar P (2019) 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.

18. Lai Z, Guo X, Cheng Z, Ruan G, Du F (2020) Green synthesis of fluorescent carbon dots from cherry tomatoes for highly effective detection of trifluralin herbicide in soil samples. Chemistry Select 5(6): 1956-1960.

19. Agnol LD, Neves RM, Maraschin M, Moura S, Ornaghi HL, et al. (2021) Green synthesis of spirulina-based carbon dots for stimulating agricultural plant growth. Sustain Mater Techno 30: e00347.

20. Wang S, Huo X, Zhao H, Dong Y, Cheng Q, et al. (2022) One-pot green synthesis of N,S co-doped biomass carbon dots from natural grapefruit juice for selective sensing of Cr(VI). Chem Phys Impact 5: 100112.

21. Mathew S, John BK, Thara CR, Korah BK, Mathew B (2023) One-pot synthesis of sustainable carbon dots for analytical and cytotoxicity studies. Biomass Conv Bioref.

22. Jeeva D, Velu KS, Mohandoss S, Ahmad N, Padmini S, et al. (2024) A facile green synthesis of photoluminescent carbon dots using *Pumpkin seeds* for ultra-sensitive $Cu^{2+}$ and $Fe^{3+}$ Ions detection in living cells. J Mol Struct 1312: 138543.

23. Mogharbel AT, Pashameah RA, Alluhaybi AA, Almahri A, Abumelha HM, et al. (2022) Development of a "*Turn-off*" fluorescent sensor for acetone from rice straw-derived carbon dots immobilized onto textile cotton mask. J Mol Liq 362: 119666.

24. Li L, Han Y, Wang L, Jiang W, Zhao H (2022) Dye plants derived carbon dots for flexible secure printing. Nanomaterials 12(18): 3168.

25. Durairaj A, Maruthapandi M, Luong JHT, Perelshtein I, Gedanken A (2022) Enhanced UV protection, heavy metal detection, and antibacterial properties of biomass-derived carbon dots coated on protective fabrics. ACS Appl Bio Mater 5(12): 5790-5799.

26. Qurtulen, Ahmad A, Shahrali HS, Khan N, Ahmad M, et al. (2024) One-pot synthesized fluorescent CDs from Syzygium cumini for metal ion sensing and cell imaging. Inorg Chem Commun 160: 111883.

27. Pricilla RB, Maruthapandi M, Durairaj A, Kuritka I, Luong JHT, et al. (2023) Biomass-derived carbon dots and their coated surface as a potential antimicrobial agent. Biomass Conv Bioref.

28. Das P, Sherazee M, Marvi PK, Ahmed SR, Gedanken A, et al. (2023) Waste-derived sustainable fluorescent nanocarbon-coated breathable functional fabric for antioxidant and antimicrobial applications. ACS Appl Mater Interfaces 15(24): 29425-29439.

29. Varman GA, Kalanidhi K, Nagaraaj P (2022) Green synthesis of fluorescent carbon dots from canon ball fruit for sensitive detection of $Fe^{3+}$ and catalytic reduction of textile dyes. Dye Pigm 199: 110101.

30. Kasibabu BSB, D'souza SL, Jha S, Kailasa SK (2015) Imaging of bacterial and fungal cells using fluorescent carbon dots prepared from *Carica papaya* juice. J Fluoresc 25: 803-810.

31. Shahraki HS, Bushra R, Shakeel N, Ahmad A, Quratulen, et al. (2023) Papaya peel waste carbon dots/reduced graphene oxide nanocomposite: From photocatalytic decomposition of methylene blue to antimicrobial activity. J Bioresour Bioprod 8(2): 162-175.

32. Singh P, Kumar S, Kumar K (2023) Biogenic synthesis of allium cepa derived magnetic carbon dots for enhanced photocatalytic degradation of methylene blue and rhodamine B dyes. Biomass Conv Bioref.

33. Dastidar DG, Mukherjee P, Ghosh D, Banerjee D (2021) Carbon quantum dots prepared from onion extract as fluorescence turn-on probes for selective estimation of $Zn^{2+}$ in blood plasma. Colloid Surf A: Physicochem Eng Asp 611: 125781.

34. Sousa DA, Ferreira LFV, Fedorov AA, do Rego AMD et al. (2022) Luminescent carbon dots from wet olive pomace: Structural insights, photophysical properties and cytotoxicity. Molecules 27(19): 6768.

35. Sawalha S, Hamed R, Assali M (2023) Parameters affecting methylene blue dye photodegradation by carbon dots prepared from olive pomace. Chemistry Select 8(14): e202300522.

36. Rajapandi S, Nangan S, Natesan T, Kumar A, Dharman G, et al. (2023) Ziziphus mauritiana-derived nitrogen-doped biogenic carbon dots: Eco-friendly catalysts for dye degradation and antibacterial applications. Chemosphere 338: 139584.

37. Zulfajri M, Sudewi S, Damayanti R, Huang GG (2023) Rambutan seed waste-derived nitrogen-doped carbon dots with l-aspartic acid for the sensing of congo red dye. RSC Adv 13(10): 6422-6432.

38. Vijeata A, Chaudhary GR, Chaudhary S, Umar A (2023) Biogenic synthesis of highly fluorescent carbon dots using azadirachta indica leaves: An eco-friendly approach with enhanced photocatalytic degradation efficiency towards malachite green. Chemosphere 341: 139946.

39. Almufarij RS, Mohamed ME (2023) Green synthesis of a carbon quantum dots-based superhydrophobic membrane for efficient oil/water separation. Materials 16(15): 5456.

40. Ma J, Jiang Y, Shen L, Ma H, Sun T, et al. (2022) Oil-water self-assembly engineering of prussian blue/quantum dots decorated graphene film for


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wearable textile biosensors and photoelectronic unit. Chem Eng J 427: 131824.

41. Jia LW, Zhang X (2023) Versatile red-emissive carbon dots for smart textiles and fluorescence sensing. ACS Appl Nano Mater 6(2): 1379-1385.
42. Wu Y, Wang R, Xie W, Ma G, Zhang A, et al. (2023) Solvent-thermal preparation of sulfur and nitrogen-doped carbon dots with pet waste as precursor and application in light-blocking fil. J Nanopart Res 25: 18.
43. Singh S, Shauloff N, Sharma CP, Shimoni R, Arnusch CJ, et al. (2021) Carbon dot-polymer nanoporous membrane for recyclable sunlight-sterilized facemasks. J Colloid Interface Sci 592: 342-348.
44. Zhang W, Li L, Yan M, Ma J, Wang J, et al. (2023) Turning waste into treasure: multicolor carbon dots synthesized from waste leather scrap and their application in anti-counterfeiting. ACS Sustainable Chem Eng 11(13): 5082-5092.
45. Ghazal H, Shaker S, El-Aziz EA (2023) Synthesis of Carbon Dots and Its Applications in Textiles. Egypt J Chem 66(12): 71-86.


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