UPM UNIVERSITI PUTRA MALAYSIA BERILMU BERBAKTI

SYNTHESIS, CHARACTERIZATION AND OPTIMIZATION OF COCOA POD HUSK CARBON QUANTUM DOTS

By

NAZATUL AKMAL BINTI NAZIBUDIN

© COPYRIGHT UPM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

November 2022

FPAS 2022 25

COPYRIGHT

All material contained within the thesis, including without limitation text, logos, icons, photographs, and all other artwork, is copyright material of Universiti Putra Malaysia unless otherwise stated. Use may be made of any material contained within the thesis for non-commercial purposes from the copyright holder. Commercial use of material may only be made with the express, prior, written permission of Universiti Putra Malaysia.

Copyright © Universiti Putra Malaysia

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

SYNTHESIS, CHARACTERIZATION AND OPTIMIZATION OF COCOA POD HUSK CARBON QUANTUM DOTS

By

NAZATUL AKMAL BINTI NAZIBUDIN

November 2022

Chairman : Mohamad Faiz Zainuddin, PhD
Faculty : Forestry and Environment

A quasi zero-dimensional carbon quantum dots were successfully synthesised from cocoa pod husk through an eco-friendly and simple hydrothermal reaction. In addition, different analysis was used to approve synthesise of the cocoa pod husks carbon quantum dots such as x-ray diffraction pattern, high resolution transmission electron microscope, fourier-transform infrared reflection spectroscopy, dynamic light scattering and zeta potential analysis. According to the characterization, the product was amorphous carbon with particle sizes 2.1-4.1 nm and contain various functional groups including hydroxyl and carbonyl. Besides, the photoluminescence (PL) intensity from cocoa pod husk carbon quantum dots can be modified through the optimization of hydrothermal parameters. The PL analysis showed the product has high photoluminescence intensity under optimized synthesis conditions with a quantum yield of 39.3% compared to non-optimized synthesis conditions (25.38%). Overall, the highest PL intensity of CQDs was successfully obtained by setting the hydrothermal temperature to 200°C for 2 hours, at a pH of 10 and a concentration of 1 mg/mL.

© COPYRIGHT UPM

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MENSINTESIS, MENCIRI DAN MENGOPTIMUMKAN TITIK KUANTUM KARBON KOKO POD

Oleh

NAZATUL AKMAL BINTI NAZIBUDIN

November 2022

Pengerusi : Mohamad Faiz Zainuddin, PhD
Fakulti : Perhutanan dan Alam Sekitar

Titik kuantum karbon (CQD) bersaiz sifar dimensi telah berjaya disintesis daripada sekam pod koko (CPH) melalui tindak balas hidroterma yang mesra alam melalui cara yang mudah. Di samping itu, analisis berbeza digunakan untuk mengesahkan sintesis titik kuantum karbon sekam pod koko seperti corak pembelauan sinar-X, mikroskop elektron penghantaran resolusi tinggi, spektroskopi pantulan fourier-transform inframerah, cahaya dinamik taburan dan analisis potensi zeta. Mengikut pencirian, produk itu adalah karbon amorf dengan saiz zarah 2.1-4.1 nm dan mengandungi pelbagai kumpulan berfungsi termasuk hidroksil dan karbonil. Selain itu, keamatan photoluminescence (PL) daripada titik kuantum karbon sekam pod koko boleh diubah suai melalui pengoptimuman parameter hidroterma. Analisis PL menunjukkan produk mempunyai keamatan fotoluminesensi yang tinggi di bawah keadaan sintesis yang dioptimumkan dengan hasil kuantum (QY) sebanyak 39.3% berbanding keadaan sintesis tidak dioptimumkan (25.38%). Secara keseluruhannya, keamatan PL tertinggi CQD berjaya diperoleh dengan menetapkan suhu hidroterma kepada 200°C selama 2 jam, pada pH 10 dan kepekatan 1 mg/mL.

© COPYRIGHT UPM

ACKNOWLEDGEMENTS

All praises to Allah, the Almighty and the Most Merciful. Alhamdulillah, first and foremost I would like to express my gratitude to my supervisory committee members especially Dr. Mohamad Faiz Zainuddin and Associate Prof Dr Che Azurahanim Che Abdullah for their guidance, suggestion and insightful comments which helped me to improve my weakness throughout the process. Without their guidance and persistence help this dissertation would not have been possible. Not to forget, Prof Dr Latifah Abd Manaf who always give encouragement during the completion of this Master Project.

My special appreciation and thank you to my beloved family, especially to my father, Mr. Nazibudin bin Ahmad and mother, Madam Salmah binti Kidam for their blessing, sacrifices and encouragement throughout my study years. To my sister Nurul Hidayah and younger brother, Amirul Aswad thank you for being my biggest supporters.

My grateful thanks also extended to my colleagues; Aimi Nadhirah, Tengku Adriana, Firdaus, Azim, Amirul and Ashery who had lent their hand to the fullest. Finally, my greatest thanks are to my close friends; Wafa, Sofea, Nabila, Aimi, Hanania Mirza, Sarah, Syamimi, Aisyah, Fauzan Mirza, Fadhli and Afiqah for their moral supports throughout my entire master research journey. Thank you so much and really appreciate it.

Nazatul Akmal Nazibudin
November 2022

© COPYRIGHT UPM

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Mohamad Faiz Zainuddin, PhD
Senior Lecturer
Faculty of Forestry and Environment
Universiti Putra Malaysia
(Chairman)

Che Azurahanim Che Abdullah, PhD
Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

____
ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 13 April 2023

© COPYRIGHT UPM

Declaration by the Graduate Student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software

Signature: ______________________ Date:__________________

Name and Matric No: Nazatul Akmal binti Nazibudin

© COPYRIGHT UPM

Declaration by Members of the Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: ______________________

Name of Chairman of Supervisory Committee: Dr. Mohamad Faiz Zainuddin

Signature: ______________________

Name of Member of Supervisory Committee: Associate Professor Dr. Che Azurahanim Che Abdullah

© COPYRIGHT UPM

TABLE OF CONTENTS

© COPYRIGHT UPM

© COPYRIGHT UPM

LIST OF TABLES

© COPYRIGHT UPM

LIST OF FIGURES

© COPYRIGHT UPM

© COPYRIGHT UPM

© COPYRIGHT UPM

LIST OF ABBREVIATIONS

CPH	Cocoa pod husk
CQDs	Carbon quantum dots
CPH CQDs	Cocoa pod husks carbon quantum dots
SQDs	Semiconductor quantum dots
CDs	Carbon dots
CNPS	Carbon nanoparticles
BCDs	Biomass carbon dots
QY	Quantum yield
BPEI	Branched polyethylenimine
PEI	Poly ethyleneimine
RM	Ringgit Malaysia
LKM	Malaysian Cocoa Board
AC	Activated carbon
BSA	Bovine serum albumin
OH	Hydroxyl
C=O	Carbonyl
COO^-	Carboxyl
SEM	Scanning Electron microscopy
HRTEM	High resolution transmission electron microscopy
XRD	X-ray diffraction
FTIR	Fourier transmission infrared
CPHE	Cocoa pod husk extract

© COPYRIGHT UPM

PL	Photoluminescence
UV	Ultra violet
HOMO	Highest occupied molecular orbital
LUMO	Lowest unoccupied molecular orbital
UCPL	Upconversion photoluminescence
NIR	Near infrared
QCE	Quantum confinement effect
EWGs	Electron withdrawing groups
NaOH	Sodium hydroxide
HCL	Hydrochloric acid
DI	Deionize water
λ_{ex}	Excitation wavelength
et al.	And other

© COPYRIGHT UPM

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Theobroma cacao, known as cocoa, is a significant fruit crop grown from cocoa beans that produce chocolate, cocoa powder, and butter. Malaysia is the world's sixth-largest processing and grinding facility for cocoa beans (Bermudez et al.., 2020). The cocoa grindings industry in Malaysia is expected to grow further to 400,000 tonnes shortly in 2023. In addition, as a byproduct of the production of cocoa beans, a massive amount of cocoa pod husk (CPH) is produced, and more than 320,00 kilogrammes of CPH are produced annually after processing (De et al., 2022). The vast majority of these wastes are left to deteriorate or are burned in the harvest field, despite the possibility of transforming them into commercially valuable commodities. However, this massive amount of unutilised feedstock might provide a steady supply of raw materials for a potential CPH biomass-based industry. This biomass waste could be turned into fertiliser, composite materials, pulp, and other things that have value (Kilama et al., 2019).

The constituents of CPH biomass are cellulose, hemicellulose, lignin, pectin, oils, and waxes (Diez et al., 2020). Among the following elements of the CPH biomass, cellulose comprises the largest proportion (Zoghlami & Paes, 2019), providing a feedstock for the production of sustainable value-added materials such as carbon quantum dots (CQDs). CQDs are a new type of carbon nanomaterial, mainly with a diameter of fewer than 10 nanometers in combination with numerous functional groups or polymer chains (Liu et al., 2020; Nazri et al., 2021). Cellulose is a polymer of $(C_6H_{10}O_5)n$ linked by -(1,4) glucosidic bonds with a regular network of intramolecular and intermolecular hydrogen bonds organised into microfibrils. Crystalline and amorphous segments are repeated and intertwined within microfibrils. The amorphous domain is known to be dissolved during the synthesis of cellulose fibres, resulting in cellulose CQDs.CQDs are categorised based on their carbon core configuration, surface classes, and properties (Liu et al., 2016). The structure of CQDs is made up of a vast number of surface groups or polymer strings, such as carboxyl, hydroxyl, and amine; hence CQDs have exceptional water solubility and are simple to combine with other products without phase separation (Travlou et al., 2018; Zhao et al., 2020).

Waste biomass from alternative sources, e.g., crop residues, wood byproducts, food, and livestock manure, is readily available and abundant. However, these raw materials need to be more consideration and attention, such as wood (Zhou et al., 2020), pineapple leaves (Ravindran et al., 2019), and banana pseudostem (Zhang et al., 2021). Therefore, the synthesis of CQDs from CPH biomass is significant because it would significantly improve the sustainability of cocoa production. In addition, it would provide answers to the multitude of issues associated with CPH disposal (Chandra et al., 2016). In the field of

© COPYRIGHT UPM

nanomaterials, a comprehensive study of the physicochemical and optical properties of CPH is required to maximise the use of organic wastes or non-wood fibres to produce CQDs (Akinjokun et al., 2021). The main objective of this work is to investigate the properties of cocoa pod husks carbon quantum dots (CPH CQDs) and the optimisation of synthesis parameters of CPH CQDs. The results obtained in this study could be used in determining further new applications for this kind of product.

1.2 Problem Statement

The expansion of cocoa production increases the proliferation of unwanted residues, such as CPH, on cocoa farms and plantations. Indeed, 10 tons of CPH are produced for every tonne of dry cocoa beans. Consequently, a big space is necessary for disposal. Thus, CPH wastes provide a significant issue for waste management. As biomass waste is enriched with carbon, CPH can be synthesised into functional nanomaterials, known as CQDs, that help manage biomass waste.

However, the characterisation of the CPH CQDs and optimisation of the synthesis procedure to generate high-quality CQDs with desired structures (e.g., size, shape, crystallinity, and amount of functional groups) are limited and cause the formation of CPH CQDs is not explored. Therefore, to create an effective pathway for large-scale processing of high-performing CPH CQDs, the synthesising, characterisation and influences of optimisation synthesise conditions (e.g., temperature, time, pH and concentrations) should be thoroughly investigated. It is very important to summarise synthesise process; the characterisation analysis and the stable synthesise parameters for the CPH CQDs because it is very important to facilitate the fabrication of successful synthetic routes for future potential novel applications.

1.3 Significant of the Study

Waste biomass from crop residues, forestry by-products, and food and livestock wastes is an abundant and cost-effective feedstock source. In this case, using waste materials as feed stocks to synthesise fluorescent CPH CQDs would be more efficient, allowing waste control through CPH CQDs. CQDs feature a variety of low-cost starting materials, ease of synthesis and surface functionalisation, luminescent luminescence, excellent photostability, and outstanding biocompatibility (Sharma et al., 2022; Alaghmandfard et al., 2021). Consequently, CPH CQDs can be developed to replace conventional SQDs, a traditional form of quantum dots that are usually expensive and cause environmental problems due to their heavy metals content (Safranko et al., 2021). A variety of methods have been developed for the synthesis of CPH CQDs, including electrochemical oxidation (Kawamata et al., 2017), hydrothermal (Liu et al., 2019), acid oxidation (Zhou & Wang, 2020), microwaves (Shikir et al., 2018), ultrasound (Askari et al., 2019) and arc discharge (Xiaohui et al., 2020) synthesis methods. However, these methods have some

© COPYRIGHT UPM

drawbacks, such as the need for a complex and time-consuming method, high temperatures and harsh synthetic conditions, and the high costs surrounding the production process (Pudza et al., 2019). Therefore, it is highly desirable to explore a new carbon source for the simple, economical, and environmentally friendly synthesis of such CPH CQDs with fluorescent down- and up-conversion properties, especially by focusing on their fluorescent properties in applied technologies.

1.4 Research Aim and Objectives

This study aims to convert the CPH biomass waste into functional materials known as CQDs. To achieve this, the specific objectives listed below need to be met:

1) To synthesise the biomass-derived CPH CQDs
2) To characterise the physicochemical and optical properties of CPH CQDs
3) To determine the optimal synthesise parameters for CPH CQDs

1.5 Research Questions

A few questions that needed to be answered in this study:

1) What is the method use to synthesise the CPH CQDs?
2) What are the physicochemical and optical properties of CPH CQDs?
3) What are the sets of stable parameters of synthesizing fluorescent CPH CQDs?

1.6 Thesis Organization

This thesis contains five (5) main chapters, which provide the outlined information for a better understanding of conducting the study as a whole;

Chapter 2 describes the comprehensive literature review on related topics crucial for this study, such as the summary of CQDs, the synthesis methods, the types of precursors used, CPH biomass waste, the characterisation and the influence of synthesis parameters on the fluorescence of CQDs.

Chapter 3 comprehensively describes the materials and methods utilised for this study. The framework for methodological study has also been supplied to summarise the flow of this investigation. This chapter also covers the analytical

© COPYRIGHT UPM

procedures and tools utilised for the characterisation analyses conducted in this study.

Chapter 4 provides the results and research findings of this study. This chapter illustrates the research findings in tables, graphs and figures. The explanations for the research findings, according to the study's objectives, are also discussed.

Chapter 5 summarises all the chapters of this thesis and draws a conclusion based on the fulfilment of the research objectives of this study. This chapter also presented the research contributions and made several recommendations towards the findings.

© COPYRIGHT UPM

REFERENCES

Adinarayana, L., Chunduri, A., Kurdekar, A., Patnaik, S., Aditha, S., Prathibha, C., & Kamisetti, V. (2017). Single step synthesis of carbon quantum dots from coconut shell: evaluation for antioxidant efficacy and hemotoxicity. Journal of Materials Sciences and Applications, 3(6): 83–93.

Ai, L., Yang, Y., Wang, B., Chang, J., Tang, Z., Yang, B., & Lu, S. (2021). Insights into photoluminescence mechanisms of carbon dots: advances and perspectives. Science Bulletin, 66(8): 839-856.

Akinjokun, A. I., Petrik, L. F., Ogunfowokan, A. O., Ajao, J., & Ojumu, T. V. (2021). Isolation and characterization of nanocrystalline cellulose from cocoa pod husk (CPH) biomass wastes. Heliyon, 7(4), e06680.

Akinjokun, A. I., Petrik, L. F., Ogunfowokan, A. O., Ajao, J., & Ojumu, T. V. (2021). Isolation and characterization of nanocrystalline cellulose from cocoa pod husk (CPH) biomass wastes. Heliyon, 7(4), e06680.

Alaghmandfard, A., Sedighi, O., Rezaei, N. T., Abedini, A. A., Khachatourian, A. M., Toprak, M. S., & Seifalian, A. (2021). Recent advances in the modification of carbon-based quantum dots for biomedical applications. Materials Science and Engineering: C, 120, 111756.

Alaghmandfard, A., Sedighi, O., Rezaei, N. T., Abedini, A. A., Khachatourian, A. M., Toprak, M. S., & Seifalian, A. (2021). Recent advances in the modification of carbon-based quantum dots for biomedical applications. Materials Science and Engineering: C, 120, 111756.

Alam, A. M., Park, B. Y., Ghouri, Z. K., Park, M., & Kim, H. Y. (2015). Synthesis of carbon quantum dots from cabbage with down-and up-conversion photoluminescence properties: excellent imaging agent for biomedical applications. Green Chemistry, 17(7): 3791–3797.

Amin, N., Afkhami, A., Hosseinzadeh, L., & Madrakian, T. (2018). Green and cost-effective synthesis of carbon dots from date kernel and their application as a novel switchable fluorescence probe for sensitive assay of Zoledronic acid drug in human serum and cellular imaging. Analytica Chimica Acta, 1030: 183-193.

Anooj, E. S., & Praseetha, P. K. (2019). Cocoa Bean-Extract Mediated Graphene Quantum Dots as Antimicrobial, Anticancer, and Plant Growth Regulators. International Journal of Recent Technology and Engineering, 8: 269-273.

Ardekani, S. R., Aghdam, A. S. R., Nazari, M., Bayat, A., Yazdani, E., & Saievar-Iranizad, E. (2019). A comprehensive review on ultrasonic spray pyrolysis technique: Mechanism, main parameters and applications in condensed matter. Journal of Analytical and Applied Pyrolysis, 141: 104631.

Bandi, R., Gangapuram, B. R., Dadigala, R., Eslavath, R., Singh, S. S., & Guttena, V. (2016). Facile and green synthesis of fluorescent carbon dots from onion waste and their potential applications as sensor and multicolor imaging agents. RSC advances, 6(34), 28633-28639.

Baweja, H., & Jeet, K. (2019). Economical and green synthesis of graphene and carbon quantum dots from agricultural waste. Materials Research Express, 6(8): 0850g8.

Bermudez, S., Voora, V., Larrea, C., & Luna, E. (2022). Cocoa prices and Sustainability.

Bhattacharya, A., Chatterjee, S., Prajapati, R., & Mukherjee, T. K. (2015). Size-dependent penetration of carbon dots inside the ferritin nanocages: evidence for the quantum confinement effect in carbon dots. Physical Chemistry Chemical Physics, 17(19): 12833–12840.

Boobalan, T., Sethupathi, M., SengottUVelan, N., Kumar, P., Balaji, P., Gulyás, B., Padmanabhan, P., Selvan, S.T. & Arun, A. (2020). Mushroom-derived carbon dots are used to detect toxic metal ions and as antibacterial and anticancer agents. ACS Applied Nano Materials, 3(6): 5910–5919.

Boruah, A., Saikia, M., Das, T., Goswamee, R. L., & Saikia, B. K. (2020). Blue-emitting fluorescent carbon quantum dots from waste biomass sources and their application in fluoride ion detection in water. Journal of Photochemistry and Photobiology B: Biology, 209: 111940.

Buendia-Kandia, F., MaUViel, G., Guedon, E., Rondags, E., Petitjean, D., & Dufour, A. (2017). Decomposition of cellulose in hot-compressed water: detailed analysis of the products and effect of operating conditions. Energy & Fuels, 32(4): 4127-4138.

Cai, X., Liu, J., Liew, W. H., Duan, Y., Geng, J., Thakor, N., Yao, K., Liao, L. D., & Liu, B. (2017). Organic molecules with propeller structures for efficient photoacoustic imaging and photothermal ablation of cancer cells. Materials Chemistry Frontiers, 1(8): 1556-1562.

Campos-Vega, R., Nieto-Figueroa, K. H., & Oomah, B. D. (2018). Cocoa (Theobroma cacao L.) pod husk: Renewable source of bioactive compounds. Trends in Food Science & Technology, 81, 172-184.

Cayuela, A., Soriano, M. L., Carrillo-Carrión, C., & Valcárcel, M. (2016). Semiconductor and carbon-based fluorescent nanodots: the need for consistency. Chemical Communications, 52(7): 1311-1326.

Chandra, S., Singh, V. K., Yadav, P. K., Bano, D., Kumar, V., Pandey, V. K., Talat, M., & Hasan, S. H. (2019). Mustard seeds derived fluorescent carbon quantum dots and their peroxidase-like activity for colorimetric detection of H2O2 and ascorbic acid in a real sample. Analytica Chimica Acta, 1054L: 145-156.

Chen, D., Wu, W., Yuan, Y., Zhou, Y., Wan, Z., & Huang, P. (2016). Intense multi-state visible absorption and full-color luminescence of nitrogen-doped carbon quantum dots for blue-light-excitable solid-state-lighting. Journal of Materials Chemistry C, 4(38): 9027–9035.

Chen, K., Qing, W., Hu, W., Lu, M., Wang, Y., & Liu, X. (2019). On-off-on fluorescent carbon dots from waste tea: Their properties, antioxidant and selective detection of CrO42−, Fe3+, ascorbic acid and L-cysteine in real samples. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 213: pp. 228–234.

Chen, T., Ren, Y., Xu, Y., Jiang, W., Wang, L., Jiang, W., & Xie, Z. (2021). Room-temperature ionic-liquid-assisted hydrothermal synthesis of Ag-In-Zn-S quantum dots for WLEDs. Journal of Alloys and Compounds, 858: 158084.

Cheng, C., Shi, Y., Li, M., Xing, M., & Wu, Q. (2017). Carbon quantum dots from carbonized walnut shells: structural evolution, fluorescence characteristics, and intracellular bioimaging. Materials Science and Engineering: C, 79: pp. 473–480.

Chunduri, L. A., Kurdekar, A., Patnaik, S., Dev, B. V., Rattan, T. M., & Kamisetti, V. (2016). Carbon quantum dots from coconut husk: evaluation for antioxidant and cytotoxic activity. Materials Focus, 5(1): 55-61.

Crevillen, A. G., Escarpa, A., & García, C. D. (2018). Carbon-based nanomaterials in analytical chemistry. Handbook of Smart Materials in Analytical Chemistry, 345(1002): 9781119422587.

Cui, L., Ren, X., Sun, M., Liu, H., & Xia, L. (2021). Carbon Dots: Synthesis, Properties, and Applications. Nanomaterials, 11(12): 3419.

Das, R., Bandyopadhyay, R., & Pramanik, P. (2018). Carbon quantum dots from natural resource: A review. Materials Today Chemistry, 8: pp. 96–109.

De Souza Vandenberghe, L. P., Valladares-Diestra, K. K., Bittencourt, G. A., de Mello, A. F. M., Vásquez, Z. S., de Oliveira, P. Z., ... & Soccol, C. R. (2022). Added-value biomolecules' production from cocoa pod husks: A review. Bioresource Technology, 344, 126252.

Deng, J., You, Y., Sahajwalla, V., & Joshi, R. K. (2016). Transforming waste into carbon-based nanomaterials. Carbon, 96: 105-115.

Devi, P., Kaur, G., Thakur, A., Kaur, N., Grewal, A., & Kumar, P. (2017). Waste-derivatized blue luminescent carbon quantum dots for selenite sensing in water. Talanta, 170: pp. 49–55.

Diao, H., Li, T., Zhang, R., Kang, Y., Liu, W., Cui, Y., Wei, S., Wang, N., Li, L., Wang, H., & Sun, T. (2018). Facile and green synthesis of fluorescent carbon dots with tunable emission for sensors and cell imaging. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 200: 226-234.

Díez, D., Urueña, A., Piñero, R., Barrio, A., & Tamminen, T. (2020). Determination of hemicellulose, cellulose, and lignin content in different types of biomasses by thermogravimetric analysis and pseudocomponent kinetic model (TGA-PKM method). Processes, 8(9), 1048.

Díez, D., Urueña, A., Piñero, R., Barrio, A., & Tamminen, T. (2020). Determination of hemicellulose, cellulose, and lignin content in different biomasses by thermogravimetric analysis and pseudo-component kinetic model (TGA-PKM method). Processes, 8(9), 1048.

Ding, H., Li, X. H., Chen, X. B., Wei, J. S., Li, X. B., & Xiong, H. M. (2020). Surface states of carbon dots and their influences on luminescence. Journal of Applied Physics, 127(23): 231101.

Ding, H., Yu, S. B., Wei, J. S., & Xiong, H. M. (2016). Full-color light-emitting carbon dots with a surface-state-controlled luminescence mechanism. ACS Nano, 10(1): 484-491.

Ding, Z., Li, F., Wen, J., Wang, X., & Sun, R. (2018). Gram-scale synthesis of single-crystalline graphene quantum dots derived from lignin biomass. Green Chemistry, 20(6): 1383-1390.

Doggaz, A., Attour, A., Mostefa, M. L. P., Tlili, M., & Lapicque, F. (2018). Iron removal from waters by electrocoagulation: Investigations of the various physicochemical phenomena involved. Separation and Purification Technology, 203: 217-225.

Doroshenko, A., Pylypenko, I., Heaton, K., Cowling, S., Clark, J., & Budarin, V. (2019). Selective Microwave-Assisted Pyrolysis of Cellulose towards Levoglucosenone with Clay Catalysts. ChemSusChem, 12(24): 5224-5227.

Dutta Choudhury, S., Chethodil, J. M., Gharat, P. M., PK, P., & Pal, H. (2017). pH-elicited luminescence functionalities of carbon dots: mechanistic insights. The Journal of Physical Chemistry Letters, 8(7): 1389–1395.

Edison, T. N. J. I., Atchudan, R., Shim, J. J., Kalimuthu, S., Ahn, B. C., & Lee, Y. R. (2016). Please turn off the fluorescence sensor for detecting ferric ions in water using green synthesised N-doped carbon dots and its bio-imaging. Journal of Photochemistry and Photobiology B: Biology, 158: 235-242.

Gao, R., Liu, Y., & Xu, Z. (2018). Synthesis of oil-based resin using pyrolysis oil produced by debromination pyrolysis of waste printed circuit boards. Journal of Cleaner Production, 203: 645-654.

Gao, Z., Zhao, C. X., Li, Y. Y., & Yang, Y. L. (2019). Beer yeast-derived fluorescent carbon dots for photoinduced bactericidal functions and multicolor imaging of bacteria. Applied Microbiology and Biotechnology, 103(11): 4585–4593.

García-Espinoza, J. D., & Nacheva, P. M. (2019). Degradation of pharmaceutical compounds in water by oxygenated electrochemical oxidation: parametric optimization, kinetic studies, and toxicity assessment. Science of The Total Environment, 691: 417-429.

Gayen, B., Palchoudhury, S., & Chowdhury, J. (2019). Carbon dots: A mystic star in the world of nanoscience. Journal of Nanomaterials, 2019.

Gedda, G., Lee, C. Y., Lin, Y. C., & Wu, H. F. (2016). Green synthesis of carbon dots from prawn shells for highly selective and sensitive detection of copper ions. Sensors and Actuators B: Chemical, 224: pp. 396–403.

Geng, T., Liu, C., Xiao, G., Lu, S., & Zou, B. (2019). Advances in the application of high pressure in carbon dots. Materials Chemistry Frontiers, 3(12): 2617-2626.

Ghamsari, M. S., Bidzard, A. M., Han, W., & Park, H. H. (2016). Wavelength-tunable visible to near-infrared photoluminescence of carbon dots: the role of quantum confinement and surface states. Journal of Nanophotonics, 10(2): 026028.

Gunjal, D. B., Gore, A. H., Bhosale, A. R., Naik, V. M., Anbhule, P. V., Shejwal, R. V., & Kolekar, G. B. (2019). Waste-derived sustainable carbon nanodots as a new approach for sensitive quantification of ethionamide and cell imaging. Journal of Photochemistry and Photobiology A: Chemistry, 376: 54-62.

Guo, L., Ge, J., Liu, W., Niu, G., Jia, Q., Wang, H., & Wang, P. (2016). Tunable multicolor carbon dots prepared from well-defined polythiophene derivatives and their emission mechanism. Nanoscale, 8(2): 729-734.

Hamid, Z. A., Azim, A. A., Mouez, F. A., & Rehim, S. A. (2017). Challenges on the synthesis of carbon nanotubes from environmentally friendly green oil using pyrolysis technique. Journal of Analytical and Applied Pyrolysis, 126: 218-229.

He, M., Zhang, J., Wang, H., Kong, Y., Xiao, Y., & Xu, W. (2018). Material and optical properties of fluorescent carbon quantum dots fabricated from lemon juice via hydrothermal reaction. Nanoscale Research Letters, 13(1): 1-7.

Herbani, Y., & Suliyanti, M. M. (2018). Concentration effect on optical properties of carbon dots at room temperature. Journal of Luminescence, 198: 215-219.

Hu, Y., Li, J., & Li, X. (2019). Leek-derived co-dopedcodoped carbon dots as efficient fluorescent probes for dichlorvos sensitive detection and multicolor cell imaging. Analytical and Bioanalytical Chemistry, 411(29): 7879-7887.

Huang, P., Xu, S., Zhang, M., Zhong, W., Xiao, Z., & Luo, Y. (2020). Green allium fistulosum derived nitrogen self-doped carbon dots for quantum dot-sensitized solar cells. Materials Chemistry and Physics, 240: 122158.

Iravani, S., & Varma, R. S. (2020). Green synthesis, biomedical and biotechnological applications of carbon and graphene quantum dots. A review. Environmental Chemistry Letters, 18(3): 703–727.

Ismar, E., & Sarac, A. S. (2019). Carbon nanomaterials: carbon nanotubes, graphene, and carbon nanofibers. In Nanotechnology in Aerospace and Structural Mechanics (pp. 1-33). IGI Global.

Issa, M. A., Abidin, Z. Z., Sobri, S., Abdul-Rashid, S., Mahdi, M. A., Ibrahim, N. A., & Pudza, M. Y. (2020). Fabrication, characterization, and response surface method optimization for the quantum efficiency of fluorescent nitrogen-doped carbon dots obtained from carboxymethylcellulose of oil palms empty fruit bunch. Chinese Journal of Chemical Engineering, 28(2): 584–592.

Janus, Ł., Radwan-Pragłowska, J., Piątkowski, M., & Bogdał, D. (2020). Coumarin-Modified CQDs for Biomedical Applications-Two-Step Synthesis and Characterization. International Journal of Molecular Sciences, 21(21): 8073.

Jeong, Y., Moon, K., Jeong, S., Koh, W. G., & Lee, K. (2018). Converting waste papers to fluorescent carbon dots in the recycling process without loss of ionic liquids and bioimaging applications. ACS Sustainable Chemistry & Engineering, 6(4): 4510-4515.

Jiang, K., Sun, S., Zhang, L., Lu, Y., Wu, A., Cai, C., & Lin, H. (2015). Red, green, and blue luminescence by carbon dots: full-color emission tuning and multicolor cellular imaging. Angewandte chemie, 127(18): 5450-5453.

Jiang, K., Zhang, L., Lu, J., Xu, C., Cai, C., & Lin, H. (2016). Triple-mode emission of carbon dots: applications for advanced anti-counterfeiting. Angewandte Chemie, 128(25): 7347-7351.

Jiang, X., Liu, J., Du, X., Hu, Z., Chang, H. M., & Jameel, H. (2018). Phenolation to improve lignin reactivity toward thermosets application. ACS Sustainable Chemistry & Engineering, 6(4): 5504–5512.

Jiao, Y., Gong, X., Han, H., Gao, Y., Lu, W., Liu, Y., Xian, M., Shuang, S., & Dong, C. (2018). Facile synthesis of orange fluorescence carbon dots with excitation independent emission for pH sensing and cellular imaging. Analytica Chimica Acta, 1042: 125-132.

John, T. S., Yadav, P. K., Kumar, D., Singh, S. K., & Hasan, S. H. (2020). Highly fluorescent carbon dots from wheat bran as a novel drug delivery system for bacterial inhibition. Luminescence, 35(6): 913-923.

Jorns, M., & Pappas, D. (2021). A Review of Fluorescent Carbon Dots, Their Synthesis, Physical and Chemical Characteristics, and Applications. Nanomaterials, 11(6): 1448.

Jothi, V. K., Ganesan, K., Natarajan, A., & Rajaram, A. (2021). Green synthesis of self-Passivated fluorescent carbon dots Derived from Rice bran for degradation of methylene blue and fluorescent ink applications. Journal of Fluorescence, 31(2): 427-436.

Kailasa, S. K., Ha, S., Baek, S. H., Kim, S., Kwak, K., & Park, T. J. (2019). Tuning of carbon dots emission color for sensing of Fe3+ ion and bioimaging applications. Materials Science and Engineering: C, 98: 834-842.

Kandasamy, G. (2019). Recent advancements in doped/co-dopedcodoped carbon quantum dots for multi-potential applications. C—Journal of Carbon Research, 5(2): 24.

Kang, C., Huang, Y., Yang, H., Yan, X. F., & Chen, Z. P. (2020). A review of carbon dots produced from biomass wastes. Nanomaterials, 10(11): 2316.

Kang, H., Wang, W., Sun, Q., Yang, S., Jin, J., Zhang, X., Ren, X., Zhang, J., & Zhou, J. (2018). Microwave-assisted synthesis of quinazolin-4 (3H)-ones catalyzed by SbCl3. Heterocyclic Communications, 24(6): 293–296.

Khalil, A. M., El-Khatib, A. M., & El-khatib, M. (2019). Synthesis of hexagonal nanozinc by arc discharge for antibacterial water treatment. Surface Innovations, 8(3): 165-171.

Khan, Z. M., Rahman, R. S., Islam, S., & Zulfequar, M. (2019). Hydrothermal treatment of red lentils for synthesizing fluorescent carbon quantum dots and its application for sensing Fe3+. Optical Materials, 91: 386-395.

Khojastehnezhad, A., Taghavi, F., Yaghoobi, E., Ramezani, M., Alibolandi, M., Abnous, K., & Taghdisi, S. M. (2021). Recent achievements and advances in optical and electrochemical autosensing detection of ATP based on quantum dots. Talanta, 122753.

Kilama, G., Lating, P. O., Byaruhanga, J., & Biira, S. (2019). Quantification and characterization of cocoa pod husks for electricity generation in Uganda. Energy, Sustainability and Society, 9(1), 1-11.

Kilama, G., Lating, P. O., Byaruhanga, J., & Biira, S. (2019). Quantification and characterization of cocoa pod husks for electricity generation in Uganda. Energy, Sustainability and Society, 9(1), 1-11.

Kumar, A., Chowdhuri, A. R., Laha, D., Mahto, T. K., Karmakar, P., & Sahu, S. K. (2017). Green synthesis of carbon dots from Ocimum sanctum for effective fluorescent sensing of Pb2+ ions and live cell imaging. Sensors and Actuators B: Chemical, 242: 679–686.

Kumar, N., Salehiyan, R., Chauke, V., Botlhoko, O. J., Setshedi, K., Scriba, M., Masukume, M., & Ray, S. S. (2021). Top-down synthesis of graphene: A comprehensive review. FlatChem, 100224.

Kurian, M., & Paul, A. (2021). Recent trends in using green sources for carbon dot synthesis–A short review. Carbon Trends, 3: 100032.

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. ChemistrySelect, 5(6): 1956-1960.

Latief, U., ul Islam, S., Khan, Z. M., & Khan, M. S. (2021). A facile green synthesis of functionalized carbon quantum dots as fluorescent probes for highly selective and sensitive detection of Fe3+ ions. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 262: 120132.

Lee, H. J., Jana, J., Ngo, Y. L. T., Wang, L. L., Chung, J. S., & Hur, S. H. (2019). The effect of solvent polarity on emission properties of carbon dots and their uses in colorimetric sensors for water and humidity. Materials Research Bulletin, 119: 110564.

Li, D., Jing, P., Sun, L., An, Y., Shan, X., Lu, X., Zhou, D., Han, D., Shen, D., Zhai, Y., & Rogach, A. L. (2018). Near-infrared excitation/emission and multiphoton-induced fluorescence of carbon dots. Advanced materials, 30(13): 1705913.

Li, J. Y., Liu, Y., Shu, Q. W., Liang, J. M., Zhang, F., Chen, X. P., Deng, X. Y., Swihart, M. T., & Tan, K. J. (2017). One-pot hydrothermal synthesis of carbon dots with efficient up-and down-converted photoluminescence for the sensitive detection of morin in a dual-readout assay. Langmuir, 33(4): 1043-1050.

Li, J., Zhang, L., Li, P., Zhang, Y., & Dong, C. (2018). One-step hydrothermal synthesis of carbon nanodots to realize the fluorescence detection of picric acid in real samples. Sensors and Actuators B: Chemical, 258: pp. 580–588.

Li, Q., Zhou, M., Yang, M., Yang, Q., Zhang, Z., & Shi, J. (2018). Induction of long-lived room temperature phosphorescence of carbon dots by water in hydrogen-bonded matrices. Nature Communications, 9(1): 1–8.

Li, Z., Wang, L., Li, Y., Feng, Y., & Feng, W. (2019). Frontiers in carbon dots: design, properties, and applications. Materials Chemistry Frontiers, 3(12): 2571-2601.

Li, Z., Zhang, Y., Niu, Q., Mou, M., Wu, Y., Liu, X., Yan, Z., & Liao, S. (2017). A fluorescence probe based on the nitrogen-doped carbon dots prepared from orange juice for detecting Hg2+ in water. Journal of Luminescence, 187: pp. 274–280.

Liang, Y., Xu, L., Tang, K., Guan, Y., Wang, T., Wang, H., & William, W. Y. (2020). Nitrogen-doped carbon dots are used as an “on–off–on” fluorescent sensor for Fe3+ and glutathione detection. Dyes and Pigments, 178: 108358.

Lin, H., Ding, L., Zhang, B., & Huang, J. (2018). Detection of nitrite based on fluorescent carbon dots by the hydrothermal method with folic acid. Royal Society Open Science, 5(5): 172149.

Lin, X., Xiong, M., Zhang, J., He, C., Ma, X., Zhang, H., Kuang, Y., Yang, M., & Huang, Q. (2021). Carbon dots based on natural resources: Synthesis and applications in sensors. Microchemical Journal, 160: 105604.

Lin, Y. S., Lin, Y., Periasamy, A. P., Cang, J., & Chang, H. T. (2019). Parameters affecting the synthesis of carbon dots for quantitation of copper ions. Nanoscale Advances, 1(7): 2553-2561.

Liu, C., Wang, R., Wang, B., Deng, Z., Jin, Y., Kang, Y., & Chen, J. (2018). Orange, yellow and blue luminescent carbon dots are controlled by the surface state for multicolor cellular imaging, light emission, and illumination. Microchimica Acta, 185(12): 1-8.

Liu, H., Ding, L., Chen, L., Chen, Y., Zhou, T., Li, H., Xu, Y., Zhao, L., & Huang, N. (2019). A facile, green synthesis of biomass carbon dots coupled with molecularly imprinted polymers for highly selective detection of oxytetracycline. Journal of Industrial and Engineering Chemistry, 69: pp. 455–463.

Liu, M. (2020). Optical properties of carbon dots: a review. Nanoarchitectonics, pp. 1–12.

Liu, M. L., Chen, B. B., Li, C. M., & Huang, C. Z. (2019). Carbon dots: synthesis, formation mechanism, fluorescence origin, and sensing applications. Green chemistry, 21(3): 449–471.

Liu, Q., Li, D., Zhu, Z., Yu, S., Zhang, Y., Yu, D., & Jiang, Y. (2018). N-doped carbon dots from phenol derivatives for excellent color rendering WLEDs. RSC advances, 8(9): 4850–4856.

Liu, Y., Huang, H., Cao, W., Mao, B., Liu, Y., & Kang, Z. (2020). Advances in carbon dots: from the perspective of traditional quantum dots. Materials Chemistry Frontiers, 4(6): 1586-1613.

Lu, F., Rodriguez-Garcia, J., Van Damme, I., Westwood, N. J., Shaw, L., Robinson, J. S., Warren, G., Chatzifragkou, A., Mason, S.M., Gomez, L., & Charalampopoulos, D. (2018). Valorisation strategies for cocoa pod husk and its fractions. Current Opinion in Green and Sustainable Chemistry, 14: pp. 80–88.

Lu, M., Duan, Y., Song, Y., Tan, J., & Zhou, L. (2018). Green preparation of versatile nitrogen-doped carbon quantum dots from watermelon juice for cell imaging, detection of Fe^{3+} ions and cysteine, and optical thermometry. Journal of Molecular Liquids, 269: 766-774.

Lu, S., Wu, D., Li, G., Lv, Z., Chen, Z., Chen, L., Chen, G., Xia, L., You, J. & Wu, Y. (2016). Carbon dots-based ratiometric nanosensor for highly sensitive and selective detection of mercury (II) ions and glutathione. Rsc Advances, 6(105): 103169-103177.

Mahat, N. A., & Shamsudin, S. A. (2020). Transformation of oil palm biomass to optical carbon quantum dots by carbonisation-activation and low temperature hydrothermal processes. Diamond and Related Materials, 102: 107660.

Malaysian Cocoa Board, https://www.koko.gov.my/lkm/index.cfm, Accessed on 20 January 2022

Meng, W., Bai, X., Wang, B., Liu, Z., Lu, S., & Yang, B. (2019). Biomass-derived carbon dots and their applications. Energy & Environmental Materials, 2(3): 172-192.

Meng, X., Chang, Q., Xue, C., Yang, J., & Hu, S. (2017). Full-color carbon dots: from energy-efficient synthesis to concentration-dependent photoluminescence properties. Chemical communications, 53(21): 3074-3077.

Miao, H., Wang, Y., & Yang, X. (2018). Carbon dots derived from tobacco for visually distinguishing and detecting three kinds of tetracyclines. Nanoscale, 10(17): 8139-8145.

Miao, P., Han, K., Tang, Y., Wang, B., Lin, T., & Cheng, W. (2015). Recent advances in carbon nanodots: synthesis, properties and biomedical applications. Nanoscale, 7(5): 1586-1595.

Mishra, V., Patil, A., Thakur, S., & Kesharwani, P. (2018). Carbon dots: emerging theranostic nanoarchitecture. Drug Discovery Today, 23(6): 1219–1232.

Mitra, S., Aravindh, A., Das, G., Pak, Y., Ajia, I., Loganathan, K., Di Fabrizio, E., & Roqan, I. S. (2018). High-performance solar-blind flexible deep-UV photodetectors based on quantum dots synthesised by femtosecond-laser ablation. Nano Energy, 48: 551-559.

Molaei, M. J. (2020). Principles, mechanisms, and application of carbon quantum dots in sensors: a review. Analytical Methods, 12(10): 1266-1287.

Mwafy, E. A., Hasanin, M. S., & Mostafa, A. M. (2019). Cadmium oxide/TEMPO-oxidized cellulose nanocomposites produced by pulsed laser ablation in liquid environment: synthesis, characterization, and antimicrobial activity. Optics & Laser Technology, 120: 105744.

Naser, H., Alghoul, M. A., Hossain, M. K., Asim, N., Abdullah, M. F., Ali, M. S., Alzubi, F. G., & Amin, N. (2019). The role of laser ablation technique parameters in synthesis of nanoparticles from different target types. Journal of Nanoparticle Research, 21(11): 1-28.

Nash, C., Glowacki, L., Gerostamoulos, D., Pigou, P., Scott, T., & Kostakis, C. (2019). Identification of a thermal degradation product of CUMYL-PEGACLONE and its detection in biological samples. Drug Testing and Analysis, 11(10): 1480-1485.

Nazri, N. A. A., Azeman, N. H., Luo, Y., & Bakar, A. A. A. (2021). Carbon quantum dots for optical sensor applications: A review. Optics & Laser Technology, 139: 106928.

Nekoueian, K., Amiri, M., Sillanpää, M., Marken, F., Boukherroub, R., & Szunerits, S. (2019). Carbon-based quantum particles: an electroanalytical and biomedical perspective. Chemical Society Reviews, 48(15): 4281-4316.

Ngu, P. Z. Z., Chia, S. P. P., Fong, J. F. Y., & Ng, S. M. (2016). Synthesis of carbon nanoparticles from waste rice husk used for the optical sensing of metal ions. New Carbon Materials, 31(2): 135-143.

Nycz, J. E., Wantulok, J., Sokolova, R., Pajchel, L., Stankevič, M., Szala, M., Malecki, J. G., & Swoboda, D. (2019). Synthesis and Electrochemical and Spectroscopic Characterization of 4, 7-diamino-1, 10-phenanthrolines and Their Precursors. Molecules, 24(22): 4102.

Oluwafemi, O. S., May, B. M., Parani, S., & Tsolekile, N. (2020). Facile, large scale synthesis of water soluble AgInSe2/ZnSe quantum dots and its cell viability assessment on different cell lines. Materials Science and Engineering: C, 106: 110181.

Ortiz, F. (2016). Theobroma cacao L. Monograph. Colegio Bolivar.

Ouattara, L. Y., Kouassi, E. K. A., Soro, D., Soro, Y., Yao, K. B., Adouby, K., Drogui, A. P., Tyagi, D. R., and Aina, P. M. (2021). Cocoa pod husks as potential sources of renewable high-value-added products: A review of current valorizations and future prospects, BioResources, 16(1), 1988-2020.

Papaioannou, N., Titirici, M. M., & Sapelkin, A. (2019). Investigating the effect of reaction time on carbon dot formation, structure, and optical properties. ACS omega, 4(26): 21658-21665.

Pareek, S., Waheed, S., Sharma, P., & Karak, S. (2020). Structural and optical properties of exfoliated graphene-like carbon nitride into nanosheets and quantum dots. Materials Characterization, 169: 110646.

Picard, M., Thakur, S., Misra, M., & Mohanty, A. K. (2019). Miscanthus grass-derived carbon dots to selectively detect Fe 3+ ions. RSC advances, 9(15): 8628–8637.

Piri, M., Sepehr, E., & Rengel, Z. (2019). Citric acid decreased, and humic acid increased Zn sorption in soils. Geoderma, 341: 39-45.

Praneerad, J., Neungnoraj, K., In, I., & Paoprasert, P. (2019). Environmentally friendly supercapacitor based on carbon dots from durian peel as an electrode. In Key Engineering Materials (Vol. 803, pp. 115-119). Trans Tech Publications Ltd.

Prathumsuwan, T., Jaiyong, P., In, I., & Paoprasert, P. (2019). Label-free carbon dots from water hyacinth leaves as a highly fluorescent probe for selective and sensitive detection of borax. Sensors and Actuators B: Chemical, 299: 126936.

Pu, J., Liu, C., Wang, B., Liu, P., Jin, Y., & Chen, J. (2021). Orange red-emitting carbon dots for enhanced colorimetric detection of Fe 3+. Analyst, 146(3): 1032-1039.

Pudza, M. Y., Abidin, Z. Z., Abdul-Rashid, S., Yassin, F. M., Noor, A. S. M., & Abdullah, M. (2019). Synthesis and characterization of fluorescent carbon dots from tapioca. ChemistrySelect, 4(14): 4140–4146.

Putro, P. A., Roza, L., & Isnaeni, I. (2018). Precursor Concentration Effect on Optical Properties of Carbon Dots from Cassava's Peels. Journal of Physics: Theories and Applications, 2(2): 43-52.

Qi, H., Teng, M., Liu, M., Liu, S., Li, J., Yu, H., Teng, C., Huang, Z., Liu, H., Shao, Q., & Guo, Z. (2019). Biomass-derived nitrogen-doped carbon quantum dots: highly selective fluorescent probe for detecting Fe3+ ions and tetracyclines. Journal of Colloid and Interface Science, 539: 332-341.

Rajasekaran, B., Singh, A., & Benjakul, S. (2022). Combined effect of chitosan and bovine serum albumin/whey protein isolate on the characteristics and stability of shrimp oil-in-water emulsion. Journal of Food Science, 87(7), 2879-2893.

Ran, Y., Wang, S., Yin, Q., Wen, A., Peng, X., Long, Y., & Chen, S. (2020). Green synthesis of fluorescent carbon dots using chloroplast dispersions as precursors and application for Fe3+ ion sensing. Luminescence, 35(6): 870-876.

Rangayasami, A., Kannan, K., Joshi, S., & Subban, M. (2020). Bioengineered silver nanoparticles using Elytraria acaulis (Lf) Lindau leaf extract and its biological applications. Biocatalysis and Agricultural Biotechnology, 27: 101690.

Raveendran, V., Babu, A. R. S., & Renuka, N. K. (2019). Mint leaf derived carbon dots for dual analyte detection of Fe (iii) and ascorbic acid. RSC Advances, 9(21): 12070-12077.

Reiss, P., Carriere, M., Lincheneau, C., Vaure, L., & Tamang, S. (2016). Synthesis of semiconductor nanocrystals, focusing on nontoxic and earth-abundant materials. Chemical Reviews, 116(18): 10731-10819.

Righetto, M., Privitera, A., Fortunati, I., Mosconi, D., Zerbetto, M., Curri, M. L., Corricelli, M., Moretto, A., Agnoli, S., Franco, L., & Ferrante, C. (2017). Spectroscopic insights into carbon dot systems. The Journal of Physical Chemistry Letters, 8(10): 2236-2242.

Rusli, A. L., & Fatah, F. A. (2022, December). A review on participation of cocoa smallholders in agricultural certification scheme. In IOP Conference Series: Earth and Environmental Science (Vol. 1114, No. 1, p. 012018). IOP Publishing.

Rusli, A. L., & Fatah, F. A. (2022, December). A review on the participation of cocoa smallholders in agricultural certification scheme. In IOP Conference Series: Earth and Environmental Science (Vol. 1114, No. 1, p. 012018). IOP Publishing.

Šafranko, S., Goman, D., Stanković, A., Medvidović-Kosanović, M., Moslavac, T., Jerković, I., & Jokić, S. (2021). An Overview of the Recent Developments in Carbon Quantum Dots—Promising Nanomaterials for Metal Ion Detection and (Bio) Molecule Sensing. Chemosensors, 9(6), 138.

Sailaja Prasannakumaran Nair, S., Kottam, N., & SG, P. K. (2020). Green synthesised luminescent carbon nanodots for the sensing application of Fe3+ ions. Journal of Fluorescence, 30(2): 357–363.

Salazar, J. C. S., Bieng, M. A. N., Melgarejo, L. M., Di Rienzo, J. A., & Casanoves, F. (2018). First typology of cacao (Theobroma cacao L.) systems in Colombian Amazonia, based on tree species richness, canopy structure and light availability. PloS one, 13(2).

Sawalha, S., Silvestri, A., Criado, A., Bettini, S., Prato, M., & Valli, L. (2020). Tailoring the sensing abilities of carbon nanodots obtained from olive solid wastes. Carbon, 167: 696-708.

Sharma, A., & Das, J. (2019). Small molecules derived carbon dots: synthesis and applications in sensing, catalysis, imaging, and biomedicine. Journal of Nanobiotechnology, 17(1): 1–24.

Sharma, V. D., Vishal, V., Chandan, G., Bhatia, A., Chakrabarti, S., & Bera, M. K. (2022). Green, sustainable, and economical synthesis of fluorescent nitrogen-doped carbon quantum dots for applications in optical displays and light-emitting diodes. Materials Today Sustainability, 19, 100184.

Shasha, P., Kim, J. H., & Park, S. J. (2019). Celery stalk-derived carbon dots for detection of copper ions. Journal of Nanoscience and Nanotechnology, 19(10): 6077–6082.

Shen, J., Shang, S., Chen, X., Wang, D., & Cai, Y. (2017). Facile synthesis of fluorescence carbon dots from sweet potato for Fe3+ sensing and cell imaging. Materials Science and Engineering: C, 76: 856-864.

Shen, S., Fu, J. J., Wang, H. B., & Gao, W. D. (2019). Advanced synthesis of carbon dots novel insights into temperature effect on fluorescent performance. Thermal Science, 23(4): 2453-2459.

Sobhani, A., & Salavati-Niasari, M. (2016). Cobalt selenide nanostructures: Hydrothermal synthesis, considering the magnetic property and effect of the different synthesis conditions. Journal of Molecular Liquids, 219: 1089-1094.

Somasundaram, G., Rajan, J., Sangaiya, P., & Dilip, R. (2019). Hydrothermal synthesis of CdO nanoparticles for photocatalytic and antimicrobial activities. Results in Materials, 4: 100044.

Song, Z., Quan, F., Xu, Y., Liu, M., Cui, L., & Liu, J. (2016). Multifunctional N, S co-dopedcodoped carbon quantum dots with pH-and thermo-dependent switchable fluorescent properties and highly selective detection of glutathione. Carbon, 104: 169–178.

Soni, N., Singh, S., Sharma, S., Batra, G., Kaushik, K., Rao, C., Verma, N.C., Mondal, B., Yadav, A., & Nandi, C. K. (2021). Absorption and emission of light in red emissive carbon nanodots. Chemical Science, 12(10): 3615–3626.

Su, A., Wang, D., Shu, X., Zhong, Q., Chen, Y., Liu, J., & Wang, Y. (2018). Synthesis of fluorescent carbon quantum dots from dried lemon peel for determination of carmine in drinks. Chemical Research in Chinese Universities, 34(2): 164–168.

Suárez Salazar, J. C., Ngo Bieng, M. A., Melgarejo, L. M., Di Rienzo, J. A., & Casanoves, F. (2018). First typology of cacao (Theobroma cacao L.) systems in Colombian Amazonia, based on tree species richness, canopy structure and light availability. PLoS One, 13(2), e0191003.

Sudolska, M., Dubecky, M., Sarkar, S., Reckmeier, C. J., Zboril, R., Rogach, A. L., & Otyepka, M. (2015). Nature of absorption bands in oxygen-functionalized graphitic carbon dots. The Journal of Physical Chemistry C, 119(23): 13369-13373.

Sun, D., Liu, T., Wang, C., Yang, L., Yang, S., & Zhuo, K. (2020). Hydrothermal synthesis of fluorescent carbon dots from gardenia fruit for sensitive on-off-on detection of Hg2+ and cysteine. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 240: 118598.

Sun, S., Guan, Q., Liu, Y., Wei, B., Yang, Y., & Yu, Z. (2019). Highly luminescence manganese doped carbon dots. Chinese Chemical Letters, 30(5): 1051-1054.

Sun, X., Liu, Y., Niu, N., & Chen, L. (2019). Synthesis of molecularly imprinted fluorescent probe based on biomass-derived carbon quantum dots for detection of mesotrione. Analytical and Bioanalytical Chemistry, 411(21): 5519-5530.

Sundaresan, P., Karthik, R., Chen, S. M., Kumar, J. V., Muthuraj, V., & Nagarajan, E. R. (2019). Ultrasonication-assisted synthesis of sphere-like strontium cerate nanoparticles (SrCeO3 NPs) for the selective electrochemical detection of calcium channel antagonists nifedipine. Ultrasonics Sonochemistry, 53: pp. 44–54.

Surendran, P., Lakshmanan, A., Priya, S. S., Geetha, P., Rameshkumar, P., Kannan, K., Hegde, T.A., & Vinitha, G. (2021). Fluorescent carbon quantum dots from Ananas comosus waste peels: a promising material for NLO behaviour, antibacterial, and antioxidant activities. Inorganic Chemistry Communications, 124: 108397.

Swapna, M. S., & Sankararaman, S. (2017). Carbon nanonecklaces with carbon nanotubes and carbon dots. International Journal of Materials Sciences, 12(3): 541-548.

Tajik, S., Dourandish, Z., Zhang, K., Beitollahi, H., Van Le, Q., Jang, H. W., & Shokouhimehr, M. (2020). Carbon and graphene quantum dots: A review on syntheses, characterization, biological and sensing applications for neurotransmitter determination. RSC Advances, 10(26): 15406–15429.

Tao, S., Lu, S., Geng, Y., Zhu, S., Redfern, S. A., Song, Y., Feng, T., Xu, W., & Yang, B. (2018). Design of metal-free polymer carbon dots: a new class of room-temperature phosphorescent materials. Angewandte Chemie International Edition, 57(9): 2393-2398.

Thangaraj, B., Solomon, P. R., & Ranganathan, S. (2019). Synthesis of carbon quantum dots with special reference to biomass as a source-a review. Current Pharmaceutical Design, 25(13): 1455–1476.

Vandarkuzhali, S. A. A., Jeyalakshmi, V., Sivaraman, G., Singaravadivel, S., Krishnamurthy, K. R., & Viswanathan, B. (2017). Highly fluorescent carbon dots from pseudo-stem of banana plant: applications as nanosensor and bio-imaging agents. Sensors and Actuators B: Chemical, 252: pp. 894–900.

Vásquez, Z. S., de Carvalho Neto, D. P., Pereira, G. V., Vandenberghe, L. P., de Oliveira, P. Z., Tiburcio, P. B., Rogez, H. L., Neto, A. G., & Soccol, C. R. (2019). Biotechnological approaches for cocoa waste management: A review. Waste management, 90: 72-83.

Vekselman, V., Feurer, M., Huang, T., Stratton, B., & Raitses, Y. (2017). Complex structure of the carbon arc discharge for synthesis of nanotubes. Plasma Sources Science and Technology, 26(6): 065019.

Vijesh, K. R., Sony, U., Ramya, M., Mathew, S., Nampoori, V. P. N., & Thomas, S. (2018). Concentration dependent variation of thermal diffusivity in highly fluorescent carbon dots using dual beam thermal lens technique. International Journal of Thermal Sciences, 126: pp. 137–142.

Wang, C., Hu, T., Wen, Z., Zhou, J., Wang, X., Wu, Q., & Wang, C. (2018). Concentration-dependent color tunability of nitrogen-doped carbon dots and their application for iron (III) detection and multicolor bioimaging. Journal of Colloid and Interface Science, 521: 33-41.

Wang, C., Xu, Z., Cheng, H., Lin, H., Humphrey, M. G., & Zhang, C. (2015). A hydrothermal route to water-stable luminescent carbon dots as nanosensors for pH and temperature. Carbon, 82: pp. 87–95.

Wang, F., Li, K., Wang, X., Li, J., Pan, J., Feng, J., Liu, K., Song, S., & Zhang, H. (2018). Thermal Decomposition of CdS Nanowires Assisted by ZIF-67 to Induce the Formation of Co9S8-Based Carbon Nanomaterials with High Lithium-Storage Abilities. ACS Applied Energy Materials, 1(11): 6242-6249.

Wang, R., Lu, K. Q., Tang, Z. R., & Xu, Y. J. (2017). Recent progress in carbon quantum dots: synthesis, properties, and applications in photocatalysis. Journal of Materials Chemistry A, 5(8): 3717-3734.

Wang, R., Wang, X., & Sun, Y. (2017). One-step synthesis of self-doped carbon dots with highly photoluminescence as multifunctional biosensors for detection of iron ions and pH. Sensors and Actuators B: Chemical, 241: 73-79.

Wang, S., Wu, S. H., Fang, W. L., Guo, X. F., & Wang, H. (2019). Synthesis of non-doped and non-modified carbon dots with high quantum yield and crystallinity by one-pot hydrothermal method using a single carbon source and used for ClO− detection. Dyes and Pigments, 164: 7-13.

Wang, Y., Sun, J., He, B., & Feng, M. (2020). Synthesis and modification of biomass derived carbon dots in ionic liquids and their application: A mini review. Green Chemical Engineering, 1(2): 94-108.

Xie, J., Bin, J., Guan, M., Liu, H., Yang, D., Xue, J., Liao, L., & Mei, L. (2018). Hydrothermal synthesis and upconversion luminescent properties of Sr2LaF7 doped with Yb3+ and Er3+ nanophosphors. Journal of Luminescence, 200: 133-140.

Xie, S., Li, S., Xiao, J., Yao, Y., & Jia, Y. (2017). Phase formation and microstructure of PbTiO3 and CaTiO3 ceramics prepared by a direct current arc discharge technique. Ferroelectrics, 506(1): 144–151.

Xue, M., Zhan, Z., Zou, M., Zhang, L., & Zhao, S. (2016). Green synthesis of stable and biocompatible fluorescent carbon dots from peanut shells for multicolor living cell imaging. New Journal of Chemistry, 40(2): 1698-1703.

Yan, F., Sun, Z., Zhang, H., Sun, X., Jiang, Y., & Bai, Z. (2019). The fluorescence mechanism of carbon dots, and methods for tuning their emission color: a review. Microchimica Acta, 186(8): 1-37.

Yang, J., Chen, W., Liu, X., Zhang, Y., & Bai, Y. (2017). Hydrothermal synthesis and photoluminescent mechanistic investigation of highly fluorescent nitrogen doped carbon dots from amino acids. Materials Research Bulletin, 89: pp. 26–32.

Yang, P., Zhu, Z., Zhang, T., Chen, M., Cao, Y., Zhang, W., Wang, X., Zhou, X., & Chen, W. (2019). Facile synthesis and photoluminescence mechanism of green-emitting xylose-derived carbon dots for anti-counterfeit printing. Carbon, 146: pp. 636–649.

Yoshinaga, T., Iso, Y., & Isobe, T. (2019). Optimizing the microwave-assisted hydrothermal synthesis of blue-emitting L-cysteine-derived carbon dots. Journal of Luminescence, 213: pp. 6–14.

Yu, P., Wen, X., Toh, Y. R., & Tang, J. (2012). Temperature-dependent fluorescence in carbon dots. The Journal of Physical Chemistry C, 116(48): 25552-25557.

Zhang, B., Jiang, Y., & Balasubramanian, R. (2021). Synthesis, formation mechanisms and applications of biomass-derived carbonaceous materials: a critical review. Journal of Materials Chemistry A.

Zhang, H., You, J., Wang, J., Dong, X., Guan, R., & Cao, D. (2020). Highly luminescent carbon dots as temperature sensors and “off-on” sensing of Hg2+ and biothiols. Dyes and Pigments, 173: 107950.

Zhang, J., Wang, Z., Zhuang, J., Kang, X., & Cheng, Z. (2017). Facile synthesis of Li4Ti5O12/Graphene nanocomposites for high performance lithium-ion batteries via a thermal-decomposition reduction in air. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 529: pp. 677–685.

Zhang, J., Zhao, X., Xian, M., Dong, C., & Shuang, S. (2018). Folic acid-conjugated green luminescent carbon dots as a nanoprobe for identifying folate receptor-positive cancer cells. Talanta, 183: pp. 39–47.

Zhang, M., Yuan, P., Zhou, N., Su, Y., Shao, M., & Chi, C. (2017). pH-Sensitive N-doped carbon dots–heparin and doxorubicin drug delivery system: preparation and anticancer research. RSC Advances, 7(15): 9347–9356.

Zhang, T., Dong, S., Zhao, F., Deng, M., Fu, Y., & Lü, C. (2019). Tricolor emissive carbon dots for ultra-wide range pH test papers and bioimaging. Sensors and Actuators B: Chemical, 298: 126869.

Zhang, X., Wang, H., Ma, C., Niu, N., Chen, Z., Liu, S., Li, J., & Li, S. (2018). Seeking value from biomass materials: Preparation of coffee bean shell-derived fluorescent carbon dots via molecular aggregation for antioxidation and bioimaging applications. Materials Chemistry Frontiers, 2(7): 1269-1275.

Zhang, Y., Liu, J., Wu, X., Tao, W., & Li, Z. (2020). Ultrasensitive detection of Cr (VI)(Cr2O72−/CrO42−) ions in water environment with a fluorescent sensor based on metal-organic frameworks combined with sulfur quantum dots. Analytica Chimica Acta, 1131: 68-79.

Zhao, B. H., Chen, J., Yu, H. Q., Hu, Z. H., Yue, Z. B., & Li, J. (2017). Optimization of microwave pretreatment of lignocellulosic waste for enhancing methane production: Hyacinth as an example. Frontiers of Environmental Science & Engineering, 11(6): 1–9.

Zhao, C., Li, X., Cheng, C., & Yang, Y. (2019). Green and microwave-assisted synthesis of carbon dots and application for visual detection of cobalt (II) ions and pH sensing. Microchemical Journal, 147: pp. 183–190.

Zheng, X. T., Ananthanarayanan, A., Luo, K. Q., & Chen, P. (2015). Glowing graphene quantum dots and carbon dots: properties, syntheses, and biological applications. Small, 11(14): 1620–1636.

Zhong, D., Miao, H., Yang, K., & Yang, X. (2016). Carbon dots originated from carnation for fluorescent and colorimetric pH sensing. Materials Letters, 166: 89-92.

Zhou, C., & Wang, Y. (2020). Recent progress in converting biomass wastes into functional materials for value-added applications. Science and Technology of Advanced Materials, 21(1), 787–804.

Zhou, Q., Xu, M., Feng, W., & Li, F. (2021). Quantum Yield Measurements of Photochemical Reaction-Based Afterglow Luminescence Materials. The Journal of Physical Chemistry Letters, 12(39): 9455–9462.

Zhou, Y., Liu, Y., Li, Y., He, Z., Xu, Q., Chen, Y., Street, J., Guo, H., & Nelles, M. (2018). Multicolor carbon nanodots from food waste and their heavy metal ion detection application. RSC advances, 8(42): 23657–23662.

Zhu, J., Chu, H., Shen, J., Wang, C., & Wei, Y. (2021). Green preparation of carbon dots from plum as a ratiometric fluorescent probe for detection of doxorubicin. Optical Materials, 114: 110941.

Zhu, J., Wu, C., Cui, Y., Li, D., Zhang, Y., Xu, J., Li, C., Iqbal, S., & Cao, M. (2021). Blue-emitting carbon quantum dots: Ultrafast microwave synthesis, purification and strong fluorescence in organic solvents. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 623: 126673.

Zhu, S., Song, Y., Zhao, X., Shao, J., Zhang, J., & Yang, B. (2015). The photoluminescence mechanism in carbon dots (graphene quantum dots, carbon nanodots, and polymer dots): current state and future perspective. Nano Research, 8(2): 355–381.

Zhuo, Y., Miao, H., Zhong, D., Zhu, S., & Yang, X. (2015). One-step synthesis of high quantum-yield and excitation-independent emission carbon dots for cell imaging. Materials Letters, 139: pp. 197–200.

Zoghlami, A., & Paës, G. (2019). Lignocellulosic biomass: understanding recalcitrance and predicting hydrolysis. Frontiers in chemistry, 7, 874.

Zulfajri, M., Abdelhamid, H. N., Sudewi, S., Dayalan, S., Rasool, A., Habib, A., & Huang, G. G. (2020). Plant part-derived carbon dots for biosensing. Biosensors, 10(6): 68.

Zulfajri, M., Rasool, A., & Huang, G. G. (2020). A fluorescent sensor based on oyster mushroom-carbon dots for sensing nitroarenes in aqueous solutions. New Journal of Chemistry, 44(25): 10525-10535.

Zuo, P., Lu, X., Sun, Z., Guo, Y., & He, H. (2016). A review on syntheses, properties, characterization and bioanalytical applications of fluorescent carbon dots. Microchimica Acta, 183(2): 519-542.

© COPYRIGHT UPM