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Green Synthesis of Carbon Nanomaterials Using Lemon Peel, Sugar Cane Bagasse, and Honey: A Comparative Study

Mohammod Tasbi Khan[1], Taufique Sami[2], Sadia Siddika[3]
Department of Materials Science & Engineering, Rajshahi University of Engineering & Technology, Rajshahi - 6204, Bangladesh
E-mail: saiyantasbi@gmail.com ,
taufiquesami408@gmail.com ,
sadiasiddika888@gmail.com

Abstract

Carbon is a crucial element, which is the backbone of life on Earth. Carbon offers vast diversity. Carbon quantum dots are an engrossing type of nanomaterials with zero dimensions. The sizes of CQDs are not more than 10 nanometers. CQDs are applied into different applications such as drug delivery, bio-sensing, solar cells, LEDs, pollutant degradation, bio-molecules and so on. CQDs can be extracted using green synthesis. Green synthesis is an approach to extract materials in an environment-friendly way. Green synthesis has great impact to the environment by utilizing renewable resources, reducing pollution, minimizing the use of toxic chemicals. CQDs are also extracting from lemon peel, sugarcane bagasse, honey which is the best example of green synthesis. The raw materials are typically bio-waste. For lemon peel the sample was prepared, chemically treated, taken through hydrothermal process and then purified to extract CQDs. For Sugar cane baggase a top –down approach was used involving chemical oxidation and exfoliation to extract CDQs. For honey a solvent free microwave process was used to heat up the honey with a organic macromolecular passivating agent and then purifying the heated, dried mixture to extract CQDs. All of the methods follow green synthesis guidelines. By following these methods, we can help the development of environment. The characterization of the synthesized CQDs is completed by High Resolution Transmission Electron Microscope, Fourier Transform Infrared Spectroscopy (FT-IR), X-ray diffraction (XRD), Raman spectroscopy, X-ray photon spectroscopy (XPS), Atomic force microscopy (AFM). This paper highlights the comparison of extraction methodology, advantages and disadvantages of the synthesized CQDs from different raw materials.

Keywords: Carbon Nanomaterials (CNMs), Carbon Quantum Dots (CQDs), Fourier Transform Infrared Spectroscopy (FT-IR), X-Ray Photon Spectroscopy (XPS), Atomic Force Microscopy (AFM).

1. Introduction

Carbon nanomaterials are among the materials that have been investigated the most because of their special qualities, which include a high specific surface area, high carrier mobility, high electrical conductivity, flexibility, and optical transparency that support their usage in sensing applications.[1][2][3] **Carbon nanomaterials** are materials made of carbon atoms with at least one dimension in the nanometer scale (1-100 nm). Carbon quantum dots (CQD) and carbon nano particles (CNPs) are some forms of carbon nanomaterials. Nanoscale carbon based particles, typically smaller than 10 nanometers are known as carbon quantum dots (CQDs). Carbon nanomaterials are typically ranging in size from 1-100 nanomaterials. There are many ways to synthesize carbon nanomaterials such as arc discharge, chemical vapor deposition, laser ablation, pyrolysis, electrochemical methods etc. But at present time green synthesis is the method that scientists and manufacturers are moving towards. Green synthesis means environmentally friendly methods used to manufacture chemical products. Green synthesis accentuates on a reliable and eco-friendly pathway with mild reactions, utilizing non-toxic precursors, and producing a lower amount of waste to ensure sustainable environment. In this review paper three different green synthesis methods of extracting carbon nano particles from lemon peel, sugar cane bagasse and honey were compared. The efficiency of extracting CQDs, the economic profitability the strength of CQDs and percentage of purity of each individual method were considered to compare. The reason to compare them was to collect data about the mentioned methods. This data was collected to use in further research and application of CQDs. Due to green chemistry, the design and production of innovative products that are safe, recyclable, and biodegradable are now underway.

2. Synthesis Method

2.1 Lemon Peel Based Synthesis of Carbon Quantum Dots (CQDs):

Lemon peels, rich in carbon and other organic compounds, provide an excellent renewable resource for synthesizing CQDs. Lemon peels are a great renewable resource for creating CQDs since they are high in carbon and other organic components. The procedure includes extracting CQDs after the peel is carbonized at high temperatures. Because these CQDs are often smaller than 10 nm and feature advantageous optical characteristics like photoluminescence, they can be used in optoelectronic and bio imaging applications.[1]

Lemon peel is a cheap and plentiful precursor in the relatively easy-to-follow synthesis process. The study's findings show that the CQDs made from lemon peels have stable photo luminescent qualities, a narrow size distribution, and good quality. This technique demonstrates how fruit waste can be used as a useful resource in nanotechnology.[1]

2.2 Sugar Cane Bagasse-Based Synthesis of Carbon Quantum Dots (CQDs):

Another useful precursor for the synthesis of CNM is sugar cane bagasse, which is the fibrous residue that remains after the juice from sugar cane is extracted. Sugar cane bagasse has cellulose that is rich in carbon and can be thermally decomposed to produce CQDs. Green chemistry principles are adhered to by this process, which also employs environmentally friendly techniques.[2]

CQDs with a consistent shape and good crystallinity were generated by the synthesis using sugar cane bagasse. It was discovered that these CQDs have advantageous fluorescence characteristics and showed promise for use in phocatalysis, bio imaging and sensing. Utilizing agricultural waste like sugarcane bagasse, lowers pollution in the environment and offers a more affordable option for producing CNM than traditional techniques.[2]

2.3 Honey-Based Synthesis of Carbon Quantum Dots (CQDs):

For the CNM, honey a substance found in nature is complex organic compound that has also been analyzed. Carbon nanoparticles are produced when honey is carbonized using heat. Honey-derived CNMs have exceptional biocompatibility because of their natural sugars and organic substances, which makes them perfect for biomedical applications like medication administration and bio imaging.[3]

3. Comparative Analysis

For lemon peel, TEM test shows that the wsCQDs are well dispersed in nature are spherical in shape. The mono dispersed CQDs have a narrow size distribution of 1-3 nm.[1] For sugarcane bagasse pulp, HRTEM imaging was done and CQDs in it were smaller in size, spherical shape. The average size is 4.1 ± 0.17nm. Crystal lattice space distance is 4.293Å. The CQDs are arranged in a FCC crystal structure. The structure of CQDs are similar to graphite.[2] For honey TEM measurements shows anhydrous state diameter. It shows the assynthesized OCN are dispersed in narrow distribution with diameter of 9±3 nm. The shape of the CQDs was confirmed to be spherical from SEM test.[3]
AFM imaging for sugarcane bagasse shows that surface roughness is less than 5nm.[2] AFM imaging for Honey shows the as synthesized OCN particles have a particle height of 11±3 nm. There is a discrepancy between particle diameter and height values which is caused by the high tendency of these particles for aggregation on a solid surface.[3]
The UV-Vis spectroscopy for lemon peel shows a continuous increase in absorption from 800-200 nm with a broad absorption band at 270 nm was found.[1] There's not very significant result found from the UV-Vis spectroscopy of sugarcane bagasse.[2] For the UV-Vis image of honey there was a broad absorbance in the 280 – 800 nm and it peaks at around 280 nm.[3]
Raman spectroscopy which is used to study the vibrational, rotational and other low frequency modes in molecules show no significant image for lemon peel.[1] For sugarcane bagasse Raman spectroscopy shows graphite nature, D-band of 1300-1400 cm^{-1} (presence of carbon nanomaterials in CQDs) and G-band of 1500-1650 cm^{-1} (provides sp^2 hybridization).[2]
X-Ray Photoelectron Spectroscopy (XPS) results for lemon peel shows five different chemical surroundings including C=C, C-C, C-H, -C-OH, -C=O bonds. These bonds confirm the hydrophilic surface functionalization of wsCQDs.[1]

4. Characterization Test

4.1 Lemon peel waste:

TEM: The size, shape and morphology of the synthesized particles at the nanoscale level are provided by Transmission Electron Microscopy (TEM).[1]
FTIR: Fourier Transform Infrared Spectroscopy (FTIR)is used to analyze the chemical structure of materials and identify functional groups.[1]
XPS: X-ray Photoelectron Spectroscopy (XPS) helps to identify the elemental composition, chemical states, and electronic state of the elements in a material.[1]

4.2 Sugarcane Bagasse Pulp:

HRTEM: High-Resolution Transmission Electron Microscopy (HRTEM) is used to analyze the crystallinity and lattice structure of materials. It offers more precise image than regular TEM.[2]
AFM: Atomic Force Microscopy (AFM) gives three-dimensional surface profiles. It analyzes surface roughness and particle size distribution of nanomaterials.[2]
Raman Spectroscopy: To characterize carbon-based materials due to its sensitivity to carbon bonding structures, Raman spectroscopy is used.[2]
XPS: To reveal the surface chemical analysis, X-ray Photoelectron Spectroscopy (XPS) is used.[2]

4.3 Honey

Raman Spectroscopy: Raman spectroscopy is a mode of test which includes shining a monochromatic light (usually from a laser) onto a sample and analyzing the scattered light.[3]
NMR Spectrometry: Nuclear Magnetic Resonance (NMR) Spectrometry is a technique where the structure of molecules is determined by observing the magnetic properties of atomic nuclei.[3]
SEM: To examine the surface structure and composition of samples at high magnification, Scanning Electron microscopy (SEM) is used.[3]
FTIR: Fourier Transform Infrared (FTIR) Spectroscopy gives information about molecular vibrations and can be used to identify functional groups and molecular structures.[3]
TEM: Transmission Electron Microscopy (TEM) is used to observe the internal structure of samples.[3]

AFM: To measure and visualize the surface topography of sample Atomic Force Microscopy (AFM) is used.[3]
Photo acoustic Spectroscopy: Photo acoustic Spectroscopy is used to analyze the absorption properties of materials by measuring the sound waves generated within a sample absorb light.[3]

Table 1: An overall comparison between CQDs extracted from lemon peel, sugarcane bagasse and honey

Characteristics	Lemon Peel	Sugarcane Bagasse	Honey
Shape of CQDs	Spherical	Spherical	Spherical
Size of CQDs	1-3 nm	4.10 ±0.17 nm	9±3 nm
UV-Vis Spectroscopy Image	Continuous increase in absorption from 800-200 nm with a broad absorption at 270 nm	No significant image	Broad absorbance from 280-800 nm and peaks at around 280 nm
Morphology	Well dispersed, narrow size distribution	Similar to graphite FCC structure	Anhydrous state
Applications	Optoelectronics, Bioimaging	Photocatalysis, Bioimaging, Sensing	Biomedical, Medicine

5. Application

5.1 Carbon Quantum Dots

- CQDs are used for cell labeling for various biological studies.
- To deliver drugs to specific cells for enhancing therapeutic efficacy and reducing side effect CQDs can be functionalized.
- To improve LEDs efficiency and color tunability CQDs are incorporated into LEDs.
- CQDs can be applied into solar cells to increase their light absorption and efficiency.
- In lasers, CQDs are used as gain media.
- CQDs are used to detect various pollutants in water.
- CQDs are useful to monitor air quality by detecting pollutants.
- To improve batteries energy density and cycle life CQDs are used as electrode.
- CQDs are used as catalyst to improve the efficiency and selectivity of various chemical reactions.
- CQDs can be functionalized as catalyst in electrochemical processes, such as fuel cells and water splitting.[1], [2], [3]

5.2 Carbon Nanoparticles:

- CNPs are used in organic light -emitting diodes and solar cells to enhance their performance.
- CNPs can be used in lubricants to reduce friction and wear.
- CNPs have excellent electrical conductivity to use in transistors, wires and other electric components.
- CNPs are mixed with composite materials to improve their strength, stiffness and conductivity.
- CNPs can be used to detect a wide range of substances.
- CNPs can be used as catalysts to improve the rate and selectivity of chemical reactions.[1], [2], [3]

Green synthesis accentuates on a reliable and eco-friendly pathway with mild reactions, utilizing nontoxic precursors, and producing a lower amount of waste to ensure sustainable environment. Due to green chemistry, the design and production of innovative products that are safe, recyclable, and biodegradable are now underway.[1], [2], [3]

6. Conclusion

Carbon quantum dots or CQDs are made from renewable resources using environmentally friendly synthesis techniques. Because of their special qualities like photoluminescence, excellent bio compatibility and environmental sustainability, they have enormous potential in a variety of sectors. A comparative analysis of CQDs made from honey, sugarcane bagasse and lemon peel shows that these materials provide an economical

and sustainable substitute for the synthesis of nanomaterials. The unique benefits that each source offers such as consistent optical characteristics and superior bio compatilbility make CQDs ideal for use in energy storage, medication delivery, bio imaging and pollution detection. Green synthesis reduces environmental effect by using less harmful chemicals, while simultaneously encouraging the usage of bio waste. This environmentally benign method fits perfectly with the increasing need in materials science and nanotechnology for sustainable technologies. As science progresses, more investigation into enhancing synthesis techniques and broadening the uses of CQDs will be essential to fulfilling their promises in a wider number of sectors.

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