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Synthesis of Aqueous Carbon Quantum Dots from *Musa Paradisiaca Linn* peels

Nur Farhana Shahrul Azhar[1], Muhammad Noor Nordin[1] & Maryam Sairi[2]
[1]Section of Medical Electronics Technology
Universiti Kuala Lumpur British Malaysian Institute
[2]ES Laboratories (M) Sdn Bhd
Bandar Sri Damansara, Kuala Lumpur, Malaysia

Corresponding email: muhammadnoor@bmi.unikl.edu.my

Abstract: *Musa Paradisiaca Linn* peels are organic waste causing serious environmental problems. With unique properties, carbon quantum dots (CQDs) have gained intense interest to be used in various applications. Herein, a facile and ecofriendly hydrothermal approach is developed for preparation of CQDs from *Musa* peels as the precursors. The resulting CQDs emit bright green fluorescence under excitation of 365 nm UV light. Photoluminescence spectroscopy measurement and power measurement were conducted to observe the optical properties of CQDs. This study presents a practical experiment approach of aqueous CQDs with homogeneous distribution and high FWHM led to futher potential application such as LED.

Keywords: CQDs, Hydrothermal, Photoluminescence, Power

1.0 INTRODUCTION

The rising field of nanotechnology has received huge interest in the synthesis of nanomaterial. Carbon quantum dots (CQDs) have become the most widely accepted emerging class of nanomaterials due to their exclusive properties such as low toxicity, aqueous compatible, excellent fluorescent, ecofriendly, tunable emission spectra and relative ease of functionalization [1,2,3]. With particle size of less than 10 nm, CQDs are a novel class of zero-dimensional carbon nanomaterials [4]. Hence, CQDs have been used in vast applications such as drug delivery [2,3,5], cell imaging [3,5,6], in vivo imaging [3], multicolor light-emitting diode (LED) [7,8], fluorescence sensing [9], antibacterial effect [10,11,12,13], anti-aging [14,15,16], cosmetics [17] and energy conversion and storage [18].

As CQDs have potential towards various fields, great efforts are focused on developing the synthesis route of CQDs and their applications. Numerous synthetic routes were reported and categorized into two routes, top-down approach (arc discharge, laser ablation and electrochemical oxidation) and bottom-up approach (thermal pyrolysis, hydrothermal and microwave-assisted) [1,9]. This synthesis route will affect the sample's size, colloidal stability and functional group which directly governs the physio-chemical and optical properties of CQDs [9,19]. However, bottom-up approach is more preferable because top-down approach used harsh conditions, required largescale production expenses and longer time to fabricate [3].

Musa Paradisiaca Linn is a scientific name for banana given by Linnaeus in 1753. In Malaysia, *Musa* fruit ranked second most widely cultivated fruit that can be utilized either ripe or unripe [20] yet 30% of the fruit is the peels which has become a waste in the food industry [21]. *Musa* peels are generally discarded instead of recycle due to less commercial use which lead to environmental problems such as excessive emission of greenhouse gases [21,22]. By utilizing the *Musa* peels to produce CQDs through ecofriendly synthesis will contribute in sustainability by turning biomass into nanomaterial. In this paper, *Musa* peels was used as precursors to produce CQDs through facile hydrothermal synthesis approach without any surface passivation. The synthesized CQDs were further characterized using photoluminescence spectroscopy measurement and power measurement.

2.0 MATERIALS AND METHODS

Musa fruits were purchased from the local market with estimation 1 week after been harvested. The CQDs were synthesized from *Musa* peels waste as precursor using the hydrothermal technique [4]. The *Musa* peels waste was rinse using DI water and transferred into a Teflon-lined stainless-steel autoclave reactor and heated up at 200°C for 6 hours. The obtained CQDs solution was then allowed to cool down to room temperature naturally and then filtered with fast-speed qualitative paper estimate of thickness around 20-25 µm to remove any larger particles before centrifuged at 4500 rpm for 20 minutes. The resultant centrifuge process will allow separation of the CQDs with unwanted particle. Then, this solution is filtered with a 0.45 µm filter and resulting CQDs solution was stored at 4°C until further characterization.

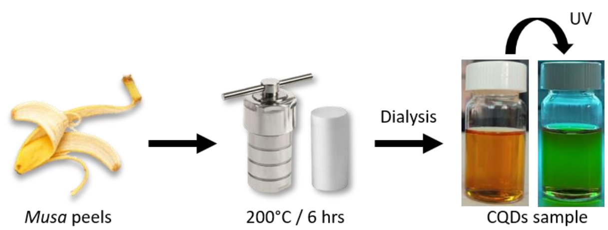

Fig. 1: Hydrothermal synthesis of CQDs sample

The photoluminescence (PL) spectroscopy measurement for the CQDs was set up as portrayed in Fig. 2. The solution of CQDs was excited by using unpolarized 365 nm UV LED diode excitation through the quartz cuvette. A long pass colour filter (Thorlabs GG400) was used to remove excitation source. PL spectrum was recorded through round-to-linear 200 µm core fiber (Thorlabs BFL200HS02) connected by Compact CCD Spectrometer (Thorlabs CCS200). For optical power measurement, the bench setup is similar however the Compact Power and Energy Meter Console (Thorlabs PM100D) was used instead of CCD spectrometer.

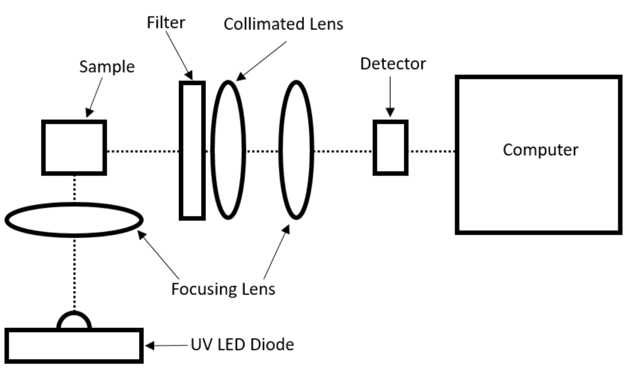

Fig. 2: Experimental setup for PL and power measurement

3.0 RESULTS

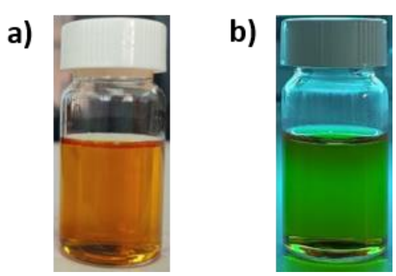

Fig. 3: Fluorescent CQDs solution under (a) daylight; (b) under 365 nm UV light

Figure 3 shows the synthesized CQDs solution exhibited a bright green colour under a UV light of 365 nm which was transparent yellow under daylight.. The maximum PL emission peak was observed at 519.79 nm upon excitation at 365 nm as shown in Fig. 4a. The PL spectra show homogenous broadening indicated single distribution of CQDs within sample. Based on PL peak spectra we estimated the bandgap of CQDs solution around ~2.4 eV. The size of aqueous CQDs is measured by using method propose by Li *et al.* [24], which indicate size of synthesis CQDs around ~2.1 nm. Fig. 4b portrayed optical power with respective wavelength for CQDs where we observed the maximum power of the CQDs sample was 12.39 µW at wavelength of 520 nm. This indicate colleration with Fig. 4a where PL peak was reported at same wavelength. The high baseline measurement at 400nm for Fig. 4b is due to UV LED irradiance suspected through long pass filter used in measurement. However, the background light power has been removed from the measurement to ensure only PL emission been recorded.

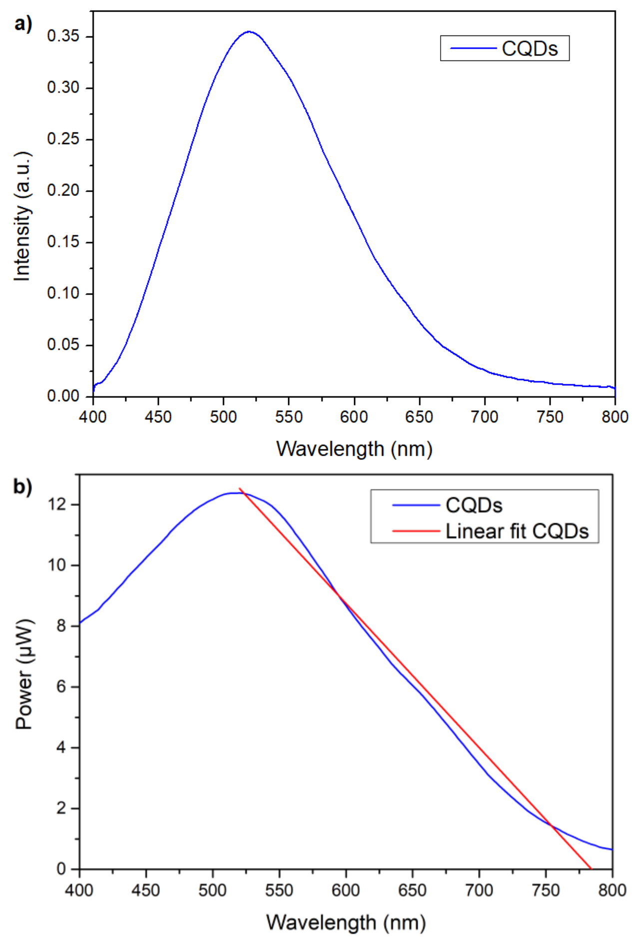

Fig. 4: The optical properties of CQDs from *Musa* peel. (a) PL emission spectra of CQDs; (b) Optical Power vs wavelength for CQDs

Gaussion fitting through PL spectra in Fig. 4a shown Full Witdth Half Maximum (FWHM) around 135.59 nm (110 meV) and integrated intensity calculated at 48.15 (a.u./nm). Linear fitting for Fig.4b from 520 nm to 800 nm shown rate of reduction of CQDs optical power at 47 nW/nm.

4.0 DISCUSSION

High FWHM indicated strong phonon-photon interaction in CQDs PL. A phonon-photon relationship is important to be measure due it indicate potential application for CQDs. Sample with high FWHM can be strong candidate for application such as LED or display in electronic field. A low FWHM can also become potential application such as detector and biosensor. Meanwhile integrated intensity measured show high number photon production during emission process. High number of photon production is important to produce display devices which has ability to tuned it brightness with respective supply power. Slow rate of reduction for optical power indicate strong bonding between individual QDs. This strong bonding lead to energy transfer between QDs also can be related to high integrated intensity calculated for CQDs.

However fast oxidation process recorded for synthesis CQDs through *Musa* peels. The synthesis sample show massive reduction on PL intensity after one month prior it synthesis. This indicate that better surface functionalization are required to improve or protect optical properties of CQDs.

5.0 CONCLUSION

In conclusion we have reported the synthesis and optical properties of CQDs from *Musa* peels. We show that through hydrothermal synthesis the production of CQDs is possible with specific synthesis route. PL spectra of CQDs also shown homogenous distribution of QDs size and high FWHM is recorded with potential application such as LED or display. Strong integrated intensity and slow rate of power reduction indicate strong bonding between individual QDs given advatages to certain application. Further synthesis route (duration and temperature) changes can be explore in future to better understand optical properties of synthesis CQDs for *Musa* peels.

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