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Newly developed carbon quantum dots for photothermal therapy and photoluminescence imaging

Nanotechnologies

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Introduction

Triple-negative breast cancer has no targeted therapy options, prompting the search for alternatives due to suboptimal clinical outcomes. Photothermal therapy (PTT) is a targeted and non-invasive treatment, based on the principle of converting light energy into heat [1]. Temperature rises (39 to 45 °C) inhibit DNA/RNA synthesis and repair, discriminatively killing temperature sensitive cancer cells. PTT uses photothermal agents, like carbon quantum dots (CQD). Nanoparticles for PTT should have sizes below 100 nm, water stability, photoluminescence (PL), high photothermal conversion, and biocompatibility. Due to their representation of normal breast tissue, and the ease of comparison with cancer models, MCF10A cells are a good cytocompatibility model.

Materials and Methods

Our innovative method uses electrochemical exfoliation to produce CQD. A custom apparatus with a graphite rod (cathode) and a metal rod (anode) in water was employed. A current with 1000 V potential difference and 60 mA intensity was used to exfoliate the graphite rod. Subsequently, large debris were removed using syringe filters with 200 nm pore size. CQD dispersions (100, 150, and 250 μg mL^{-1}) were exposed to custom-developed near infrared (NIR)-LED irradiation (30 min, 1 W cm^{-2}) and temperature increase recorded. MCF10A cells were seeded at a density of 2.5 × 10^4 cells/well in a 48 well-plate, 24h prior incubation with CQD for 3 days, then cell culture media was removed and resazurin 10% added to determine metabolic activity through fluorimetry.

Results

- CQD present average lateral sizes of 8-10 nm and a surface charge of -33.3 mV
- Typical D, G, and 2D bands are present in CQD Raman spectrum
- CQD present excitation/emission peaks at 340/448 nm wavelengths
- CQD could increase temperature until 51°C under NIR irradiation
- CQD were cytocompatible with MCF10A cells, demonstrating potential for PTT

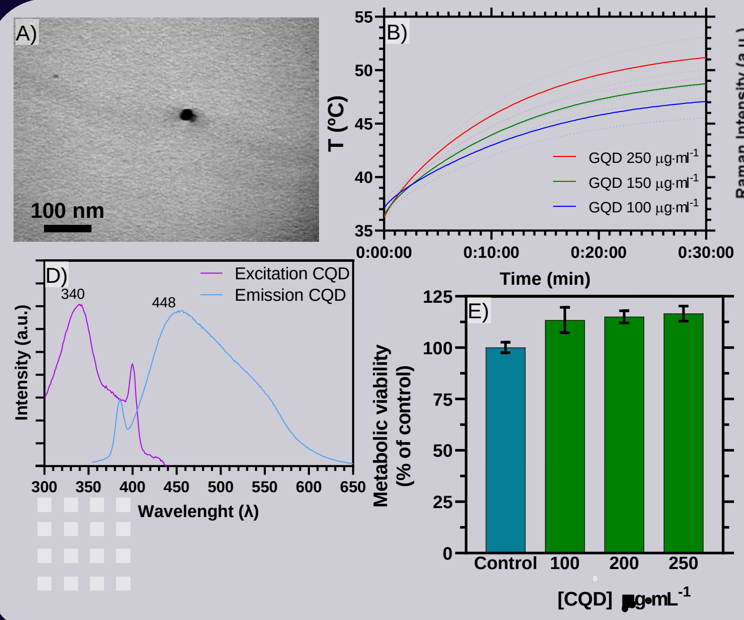

Figure 1. CQD morphology and properties. A) TEM image of CQD. B) Photothermal heating curves of CQD (100, 150 and 250 μg·mL^{-1}). C) Raman spectrum of CQD. D) Photoluminescence spectrum of CQD. E) MCF10A cells metabolic activity after 3 days exposure to CQD.

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[1] Artur M. Pinto, A. M. Pereira, I. C. Gonçalves (2020). Carbon Biomaterials. In Wagner WR, Sakiyama-Elbert SE, Zhang G, Yaszemski MJ (Ed.), Biomaterials Science. An Introduction to Materials in Medicine, 4th ed. San Diego, California: Elsevier. ISBN: 9780128161371.