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Ultra-Fast Fluorescence Quenching-Based Pesticide Detection Using Carbon Quantum Dots

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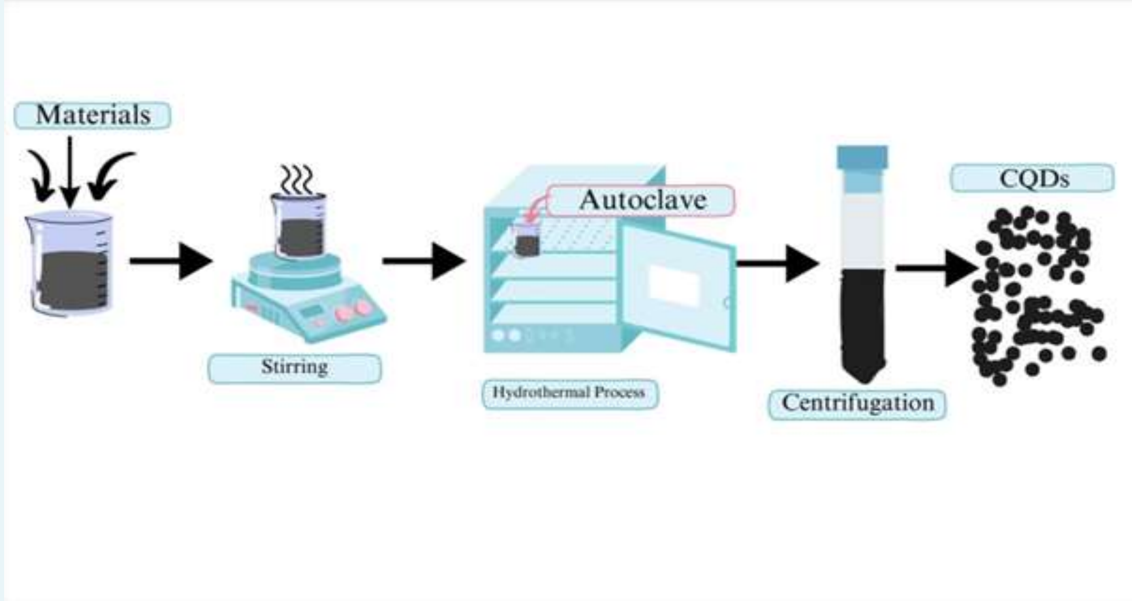
INTRODUCTION

- In this project, an ultra-fast fluorescence quenching-based detection method for the pesticide 2,4-D was developed using eco-friendly carbon quantum dots (CQDs) synthesized from spent coffee grounds. CQDs stand out due to their cost-effectiveness, biocompatibility, and high fluorescence stability. While providing a more sustainable and practical alternative to conventional methods, this approach directly contributes to the monitoring and protection of water resources. Furthermore, the valorization of coffee waste renders the project both economically and ecologically valuable.

MATERIALS & METHODS



CQD Hydrothermal Synthesis Process.

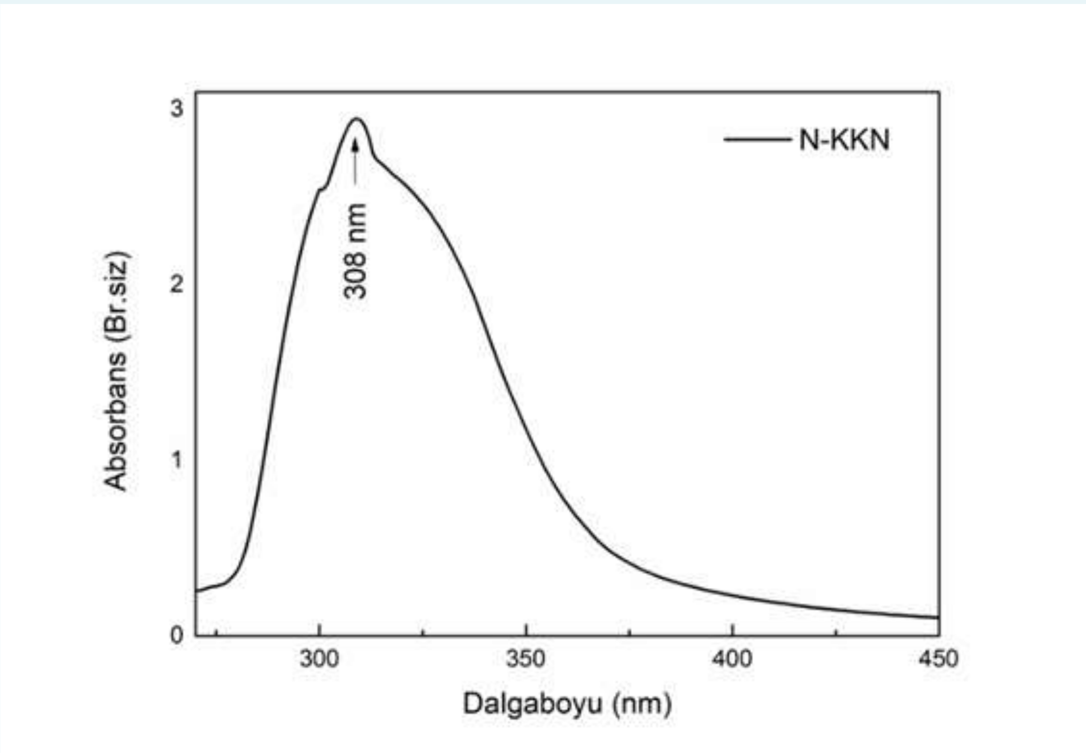
Before pesticide addition

After pesticide addition

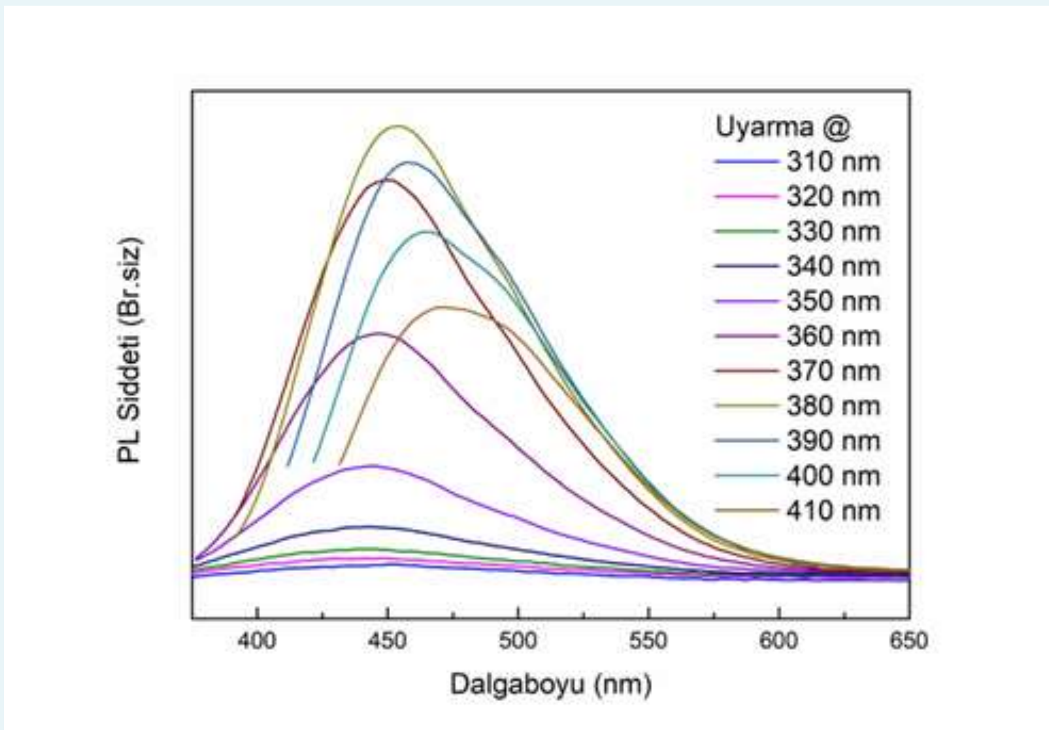
Fluorescence quenching mechanism.

- **Synthesis of N-CQDs:** Dried coffee grounds (1 g in 10 mL DI water) underwent hydrothermal reaction at 180 °C for 4 h, followed by centrifugation (6,000 rpm, 30 min) to collect the supernatant (pH 6-8, stored at +4 °C).
- **Characterization:** Optical properties were evaluated via UV-Vis and PL spectroscopy (excitation at 310-410 nm, pH 7.0 ± 0.5), quantum yield was calculated using quinine sulfate, and morphology was imaged by STEM.
- **2,4-D Detection:** Standard 2,4-D solutions were mixed with the N-CQD dispersion, and fluorescence intensity changes were monitored via PL spectroscopy for quantitative sensing.

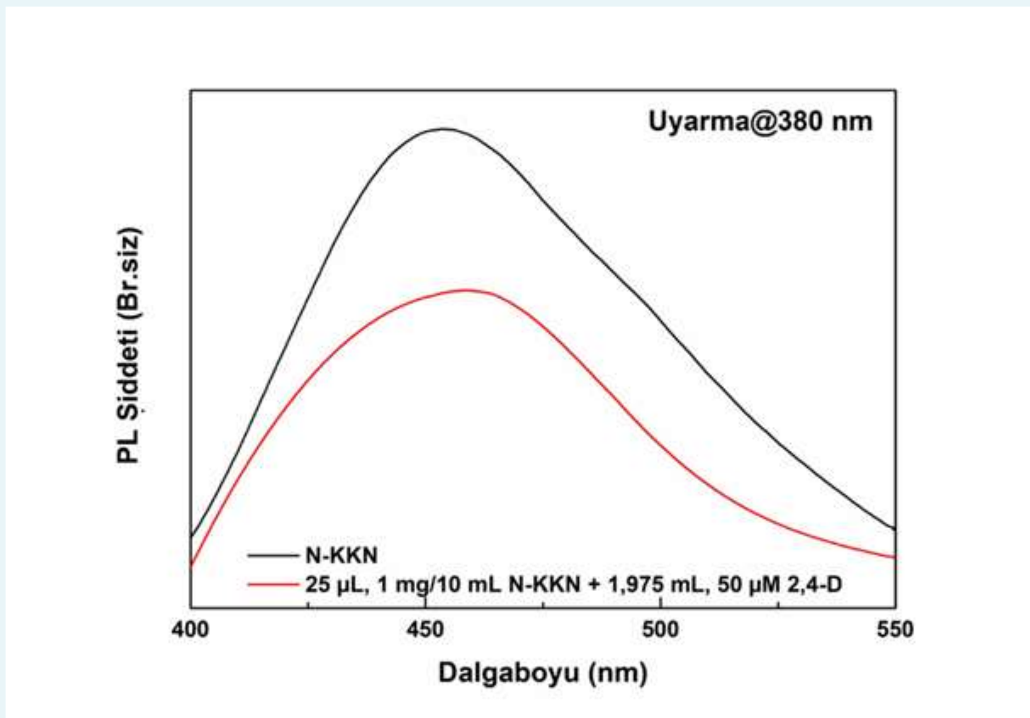
RESULTS



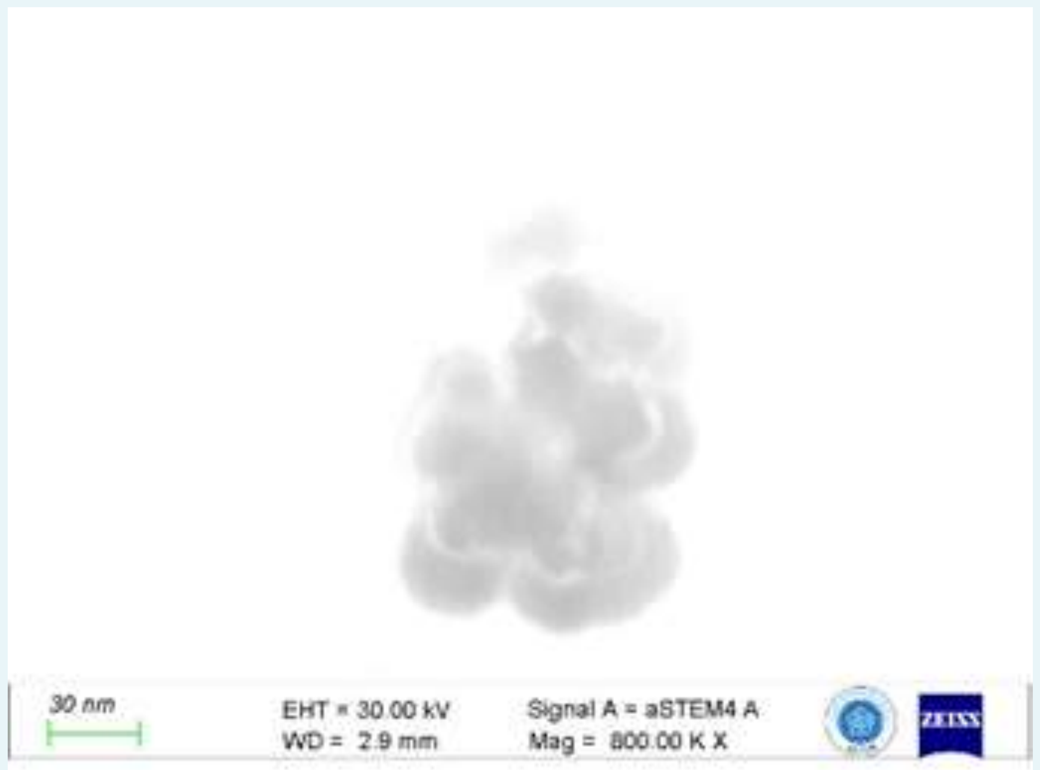
- **UV-Vis Absorbance & Fluorescence Observation** N-CQDs exhibited a characteristic absorption peak at 308 nm in the UV-Vis spectrum, corresponding to the $\pi \rightarrow \pi^*$ electronic transition of the carbon core. Under 365 nm UV light, the N-CQD dispersion displayed a distinct blue-green emission, whereas a visible quenching in fluorescence intensity occurred upon the addition of 50 µM 2,4-D.



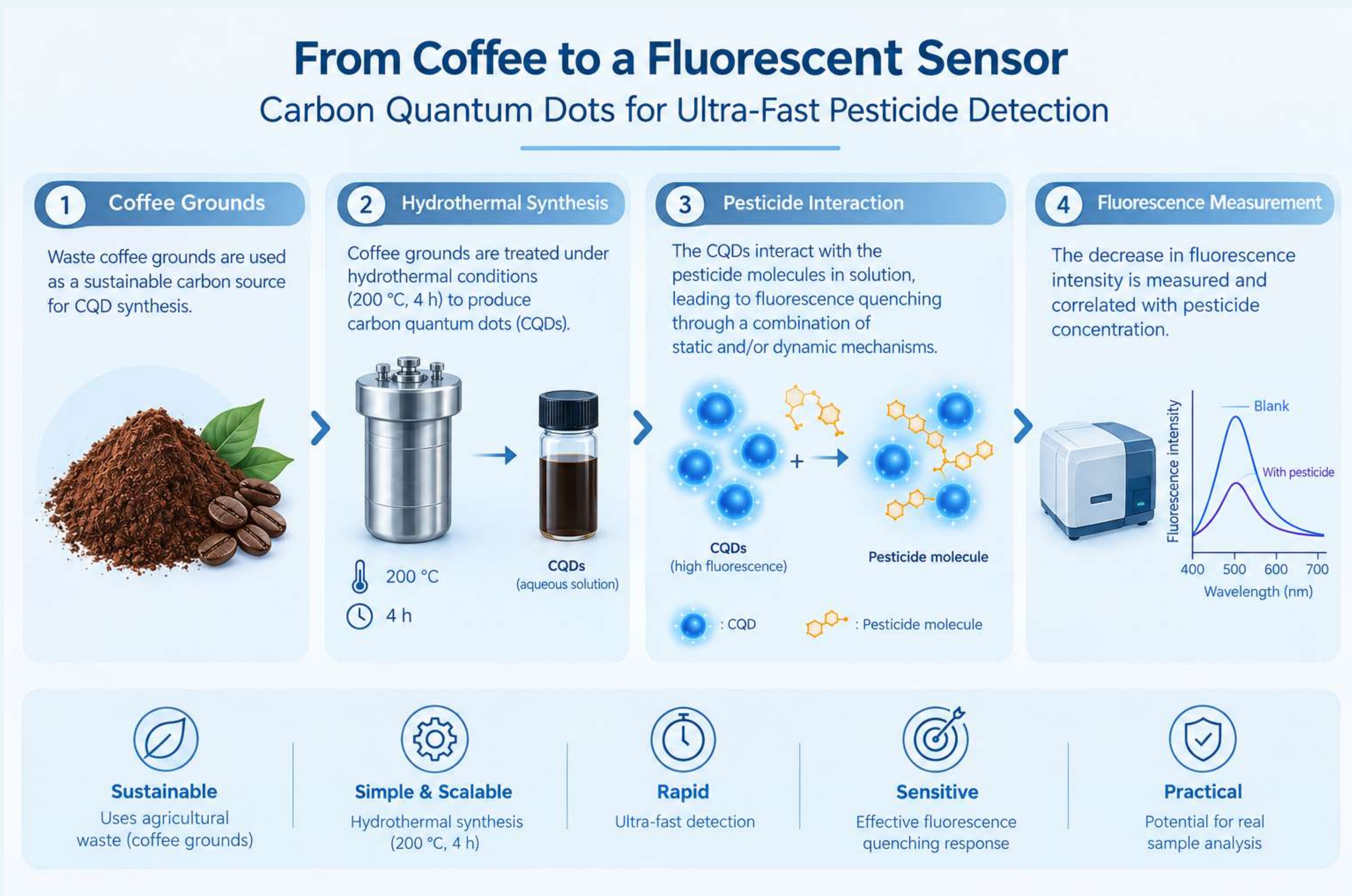
- **Photoluminescence (PL) Spectroscopy** PL spectra recorded in the 310-410 nm range revealed that the emission was centered at 450-460 nm across all excitation conditions. The strongest signal was obtained at 380 nm excitation, which was designated as the optimum analytical condition.



- **2,4-D Pesticide Detection - Fluorescence Quenching** Under 380 nm excitation, a notable decrease in the emission peak at 450 nm was observed upon the addition of 50 µM 2,4-D. The extent of quenching was directly proportional to the pesticide concentration, exhibiting a linear correlation described by the Stern-Volmer equation. The selective "turn-off" response of N-CQDs toward 2,4-D confirms the sensor's feasibility for quantitative determination.



- **STEM Morphological Analysis** At 800,000× magnification, N-CQDs formed ~30 nm clusters, while imaging at 1,000,000× magnification revealed individual particles with spherical morphology and sizes <10 nm.



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CONCLUSİON

Hydrothermally synthesized N-CQDs from spent coffee grounds exhibited characteristic optical properties (absorbance at 308 nm, emission at 450-460 nm) and uniform spherical morphology (<10 nm), in line with biomass-derived carbon dots [1]. The developed platform offers analytical performance comparable to waste-derived sensors in the literature [1,2]. Overall, this study demonstrates a low-cost, portable, and eco-friendly alternative to conventional GC-MS/HPLC methods for rapid 2,4-D pesticide detection. Future work will target real sample matrices (e.g., tap water, vegetable extracts).