From Trash to Nano-Treasure: Engineering Sustainable, Safe, and Biodegradable Quantum Dots for Use in Bioimaging, Medicine, and Agriculture

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Quantum dots (QDots) are nanoparticles with a wide range of applications, including bioimaging, fluorescent labeling, and agriculture. Commercial QDots are synthesized using heavy metals, making them harmful to our environment. This project aimed to synthesize safe and sustainable QDots from waste materials: tea and coffee grounds, banana peels, spinach, bougainvillea, and mango leaves. This study included synthesizing the six QDots; characterizing spectral properties and size/distribution using a Scanning Electron Microscope (SEM); testing potential cytotoxic effects in human cell lines; evaluating uptake into cells using fluorescence microscopy; and testing their application in agriculture. Results revealed that tea, coffee, and banana QDots fluoresced blue under ultraviolet light with maximum emissions at 446nm, 436nm, and 434nm respectively. Spinach, bougainvillea, and mango QDots fluoresced red, all having maximum emissions at 675 nm. SEM imaging sized the QDots at: coffee (15nm), tea (50-100nm), spinach (100-200nm), bougainvillea (500nm), and mango (25-50nm). Quantum yield calculation found coffee at 3.121%, tea at 2.847%, banana at 1.372%, spinach at 4.464%, bougainvillea at 1.599%, and mango at 2.901%. Safety testing showed that none of the QDots were cytotoxic. Red QDots were successfully engulfed by a macrophage cell line, making them viable for bioimaging, drug delivery and immunostaining. Blue QDots were tested as nano-fertilizers, with coffee increasing mung bean shoot length by 21%, root length by 40%, and number of secondary roots by 50%. Therefore, the results from this study confirm that QDots made from organic waste materials can serve as sustainable and viable alternatives to toxic heavy metal-based QDots.

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