



Utilization of carbon nanodots for growth inhibition of bacteria and free radical scavenging



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Abstract

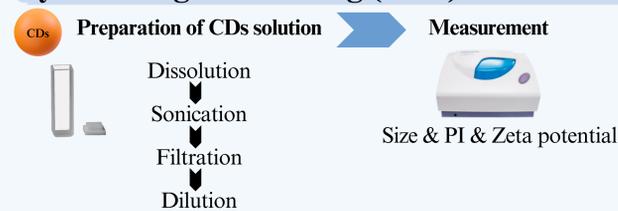
Carbon nanodots are a type of nanoparticles that have recently gained significant interest due to their outstanding properties such as biocompatibility, low toxicity, fluorescence, antibacterial and antioxidant activities. The objectives of this research are to characterize several parameters of carbon nanodots synthesized from sucrose, namely SCDs-PEI and SCDs-PEI+BZC, and to study the ability of these carbon nanodots as antibacterial and antioxidant agents. The characterization of both types of carbon nanodots using dynamic light scattering (DLS) revealed that SCDs-PEI+BZC had an average size of 52.5 ± 3.0 nm and a polydispersity index (PI) of 0.276 ± 0.117 , while the average particle size of SCDs-PEI particle was unable to be measured. The SCDs-PEI and SCDs-PEI+BZC particles exhibited zeta potential values of $+39.1 \pm 3.4$ and $+56.3 \pm 7.5$ mV, respectively. After testing the growth inhibition of *Escherichia coli* and *Staphylococcus aureus* using broth dilution technique, SCDs-PEI+BZC particles were capable of inhibiting both *E. coli* and *S. aureus* with the minimum inhibitory concentration (MIC) of $30 \mu\text{g/mL}$ and $1 \mu\text{g/mL}$, respectively, while the SCDs-PEI particles could not inhibit the growth of two bacterial species tested. Agar disk diffusion technique revealed that SCDs-PEI+BZC was able to inhibit the growth of both *E. coli* and *S. aureus*, with the MICs of $20 \mu\text{g/mL}$ and $1 \mu\text{g/mL}$, respectively. However, SCDs-PEI showed no inhibitory effect against either *E. coli* or *S. aureus*. The antioxidant activity of the carbon nanodots was assessed using DPPH and ABTS assays. The IC₅₀ values obtained from the DPPH and ABTS assays were 113.18 ± 4.26 and $93.06 \pm 0.69 \mu\text{g/mL}$ for SCDs-PEI, and 278.22 ± 0.85 and $321.70 \pm 5.22 \mu\text{g/mL}$ for SCDs-PEI+BZC, respectively. It is anticipated that the outcome from this research will become an initial platform for the development of new alternative nanoparticles to be applied as antimicrobial agents in disinfectants or as biomaterials for the treatment of diseases such as cancer.

Introduction

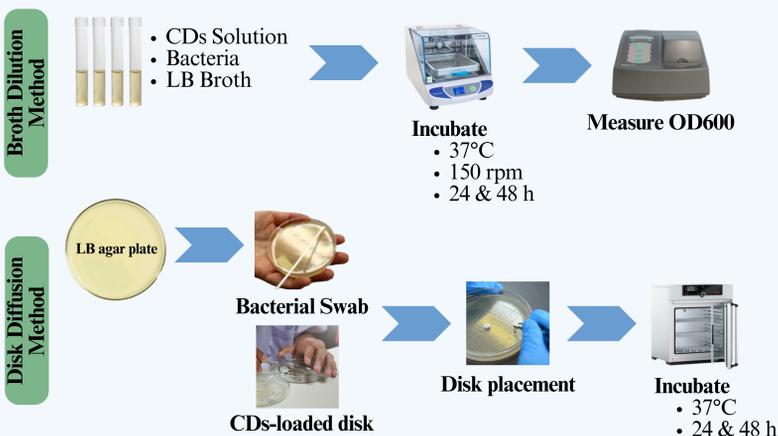
Carbon nanodots (CDs) are a fascinating class of nanomaterials that have garnered significant attention in recent years due to their unique properties, including excellent biocompatibility, low toxicity, and remarkable photoluminescence. These properties make them promising candidates for various applications, such as bioimaging, drug delivery, and sensing. In this study, we focus on the characterization, and evaluation of the antibacterial and antioxidant properties of two types of CDs derived from sucrose: sucrose carbon nanodots-polyethyleneimine (SCDs-PEI) and sucrose carbon nanodots-polyethyleneimine modified with benzalkonium chloride (SCDs-PEI+BZC).

Methodology

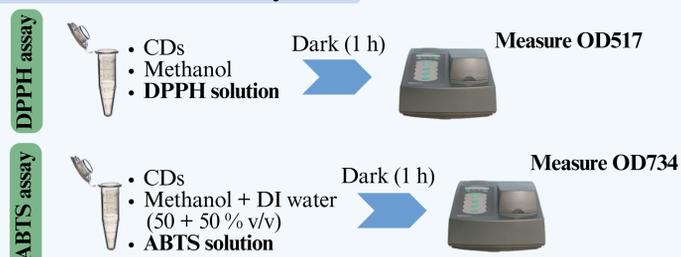
Physicochemical Characterization of CDs Using Dynamic Light Scattering (DLS)



Antimicrobial Activity Test



Antioxidant Activity Test



References

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Acknowledgements

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Results and Discussion

Physicochemical Characterization of CDs Using DLS

Table 1. Average size, polydispersity index and zeta potential of CDs.

CDs	Size (nm)	PI	Zeta Potential (mV)
SCDs-PEI	N/A	N/A	$+39.1 \pm 3.4$
SCDs-PEI+BZC	52.5 ± 3.0	0.276 ± 0.118	$+56.3 \pm 7.5$

DLS analysis revealed that SCDs-PEI+BZC had an average size of 52.5 ± 3.0 nm and a polydispersity index (PI) of 0.276 ± 0.117 . The average particle size of SCDs-PEI could not be measured. The zeta potential values of SCDs-PEI and SCDs-PEI+BZC were $+39.1 \pm 3.4$ mV and $+56.3 \pm 7.5$ mV, respectively.

Antimicrobial Activity Test

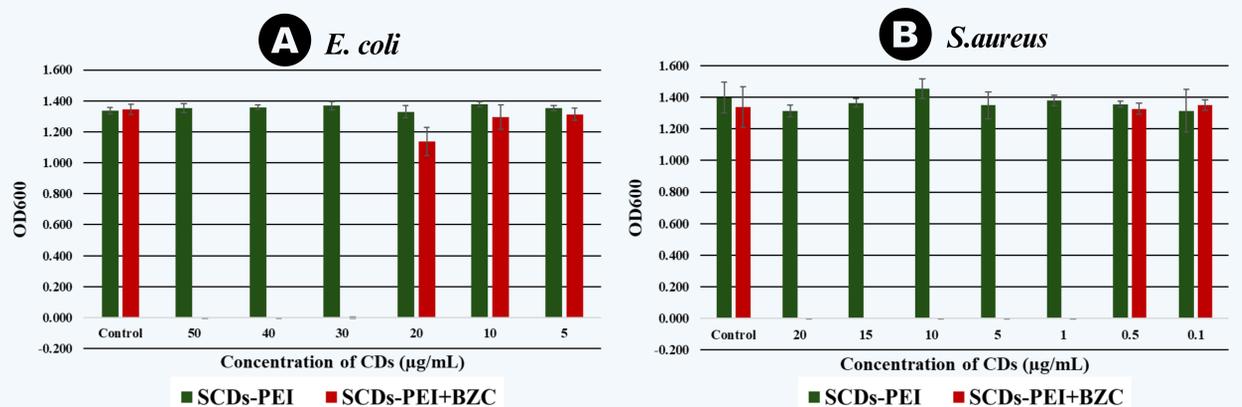


Figure 1. Antimicrobial activity test using broth dilution method. (A) *E. coli* treated with different concentrations of CDs and (B) *S. aureus* treated with different concentrations of CDs. The data were collected at 48 h after bacterial inoculation.

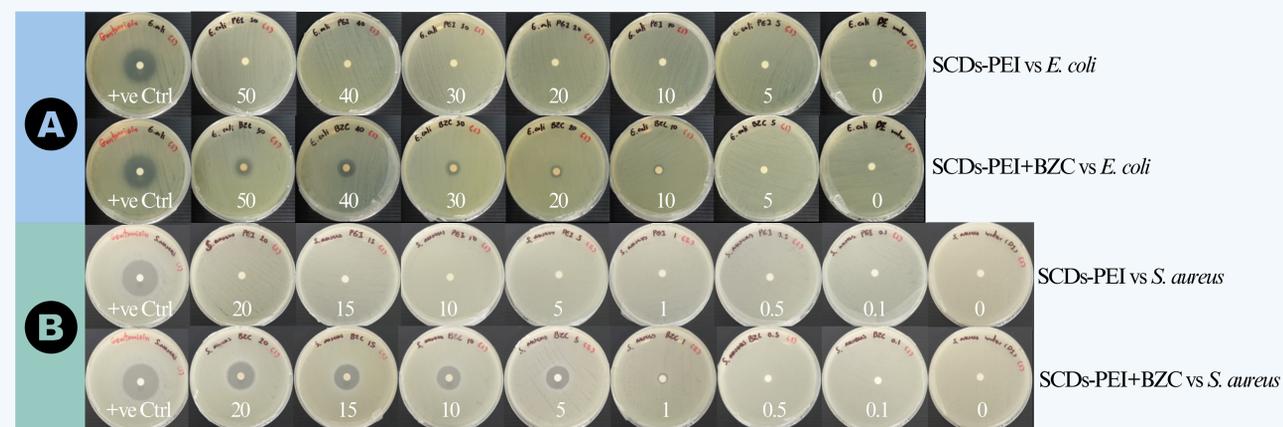


Figure 2. Antimicrobial activity test using disk diffusion method. (A) *E. coli* treated with different concentrations of CDs ranging from 0 to $50 \mu\text{g/mL}$ and (B) *S. aureus* treated with different concentrations of CDs ranging from 0 to $20 \mu\text{g/mL}$. The photographs were recorded at 48 h after bacterial swab.

SCDs-PEI+BZC showed antibacterial activity against *E. coli* (MIC: $30 \mu\text{g/mL}$ broth, $20 \mu\text{g/mL}$ disk) and *S. aureus* (MIC: $1 \mu\text{g/mL}$ broth/disk). SCDs-PEI had no activity.

Antioxidant Activity Test

Table 2. Antioxidant activity of CDs and standard trolox obtained from DPPH and ABTS assays.

Method	IC ₅₀ ($\mu\text{g/mL}$)		
	Trolox	SCDs-PEI	SCDs-PEI+BZC
DPPH	4.77 ± 0.06	113.18 ± 4.26	278.22 ± 0.85
ABTS	8.53 ± 0.14	93.06 ± 0.69	321.70 ± 5.22

Both SCDs-PEI and SCDs-PEI+BZC showed antioxidant activity. However, the antioxidant activity of both CDs were less effective compared to that of the standard trolox.

Conclusions

- SCDs-PEI+BZC had an average size in a nanoscale with a narrow size distribution, whereas SCDs -PEI size was not measurable.
- Both SCDs-PEI+BZC and SCDs -PEI were positively charged.
- Only SCDs-PEI+BZC exhibited antibacterial activity against *E. coli* and *S. aureus*.
- Both SCDs-PEI+BZC and SCDs -PEI exhibited antioxidant activity.