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Photodynamic antimicrobial decontamination of food packaging using a chitosan–Zn(II) protoporphyrin IX conjugate

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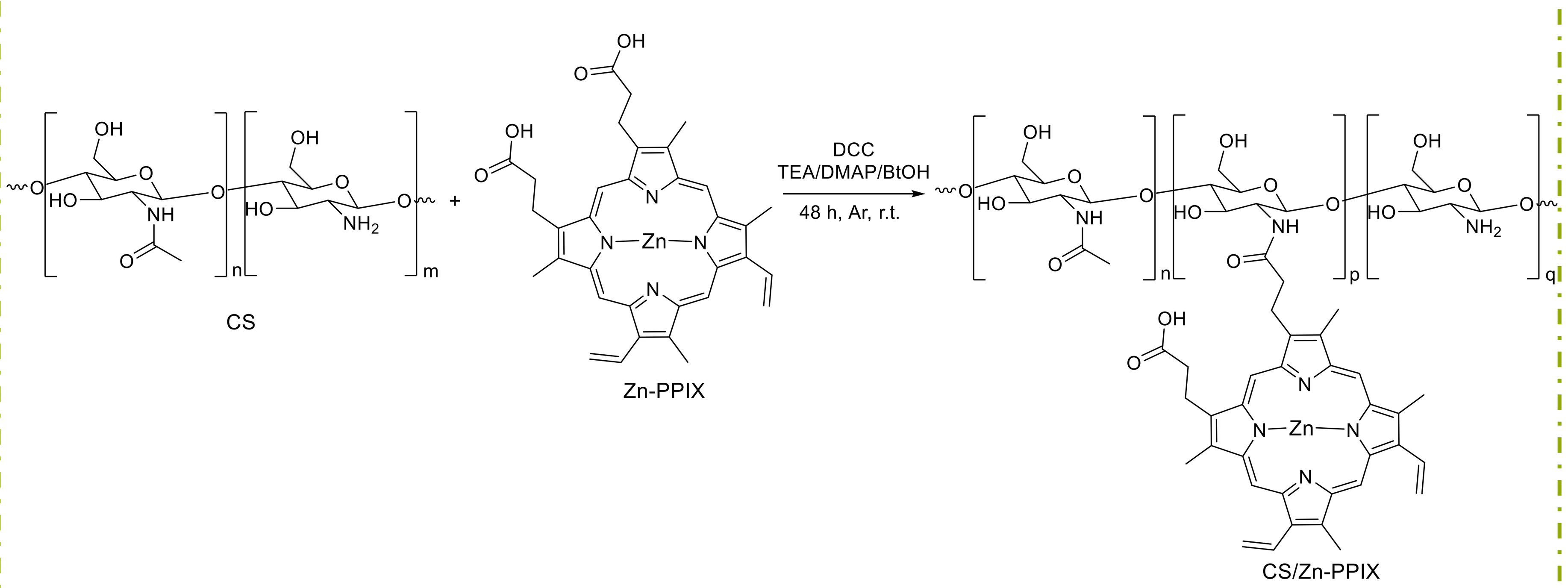
INTRODUCTION & AIM

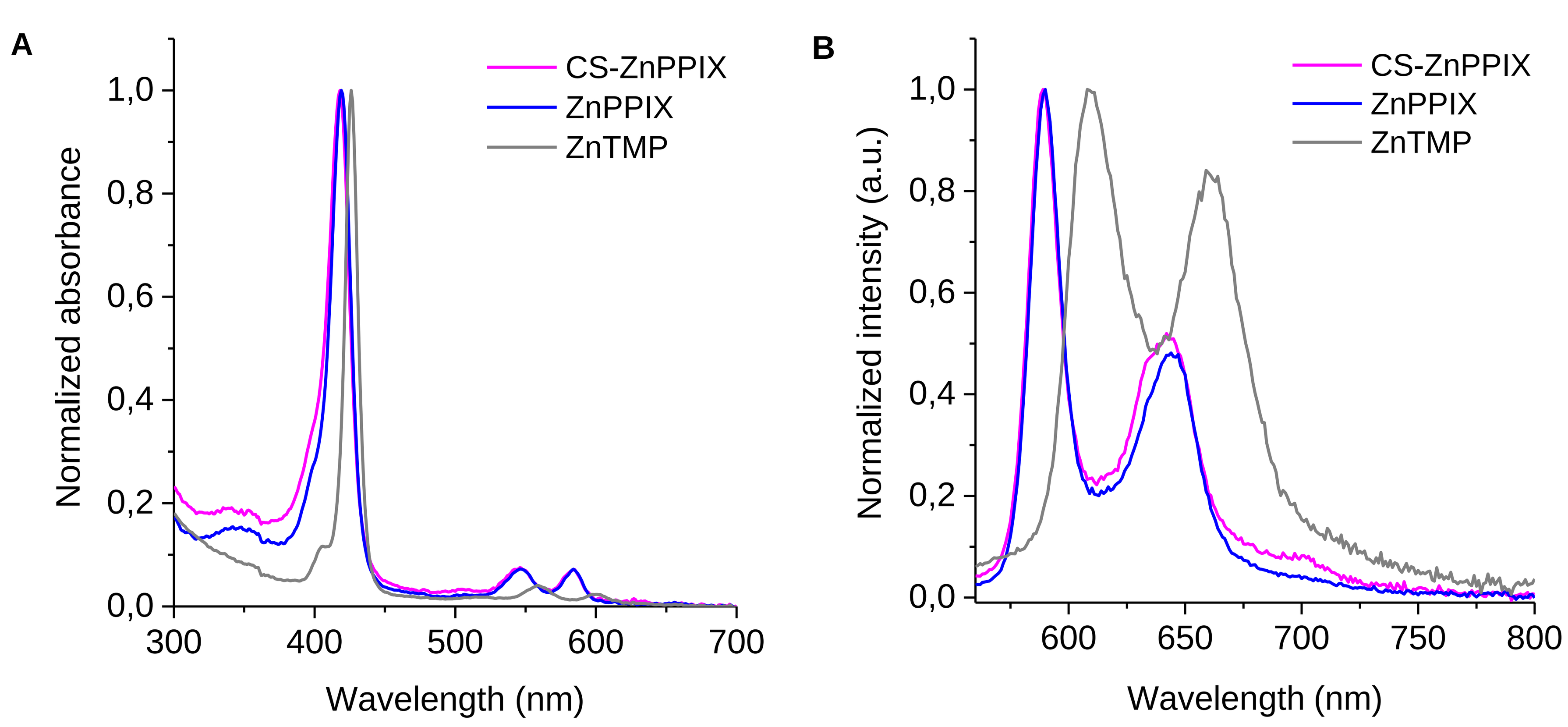
Effective decontamination methods are essential for minimizing the presence of harmful microorganisms in fresh foods. The incorporation of bioactive compounds in **packaging processes** stands out as one of the most effective approaches to maintain food quality and enhance **food safety**. This study focuses on the synthesis of a conjugate, CS-ZnPPIX, formed by linking **Zn(II) protoporphyrin IX** (ZnPPIX) with **chitosan** (CS). The aim was to create a naturally-derived polymeric material capable of reducing microbial contamination in food packaging through **photodynamic inactivation** (PDI) of pathogens.

METHOD

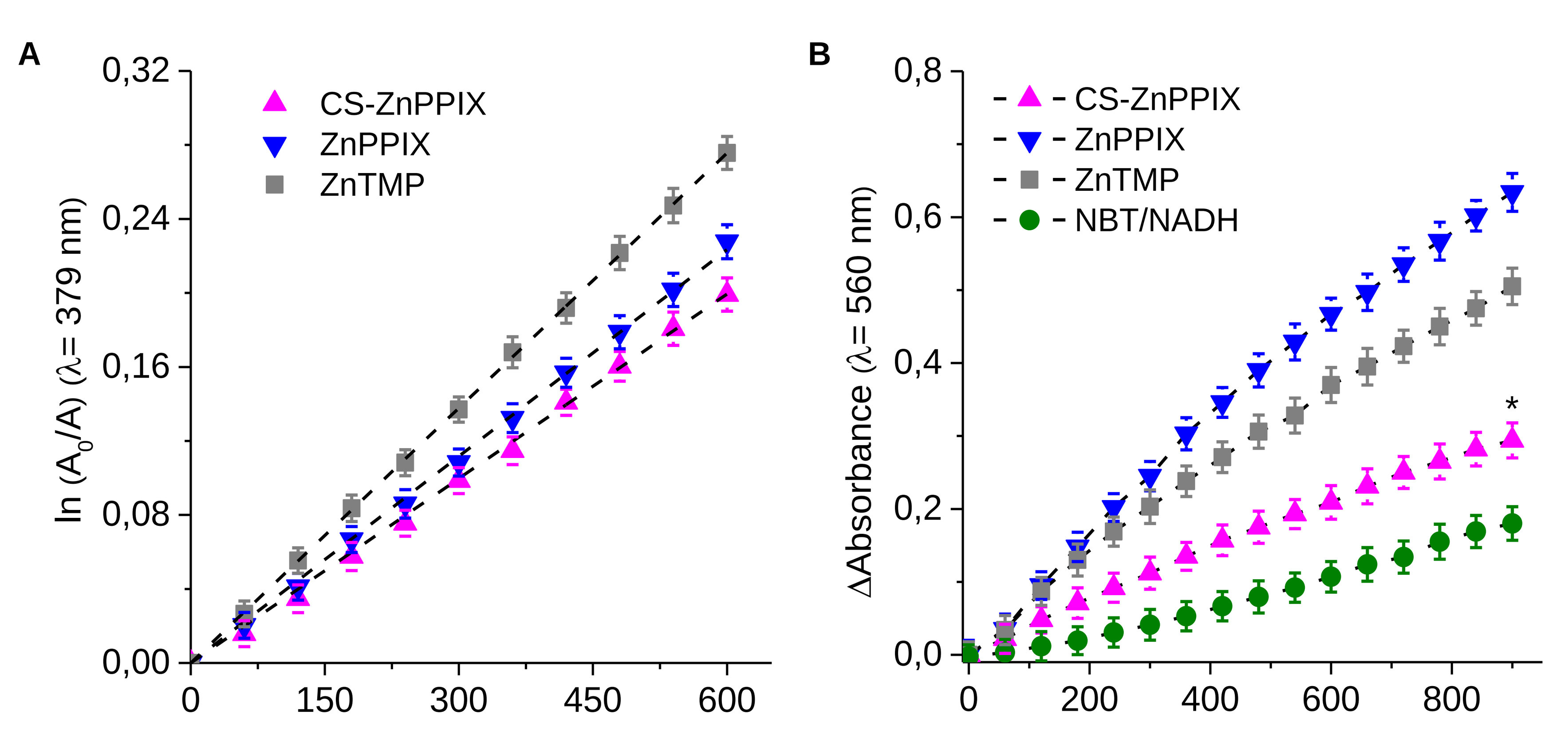
CS-ZnPPIX was obtained following the procedure reported for similar conjugates with some modifications.[1]



Once synthesized, its spectroscopic and photodynamic properties were determined, showing CS-ZnPPIX could generate singlet oxygen (Φ_Δ = 0.49)[2] and superoxide anion radicals.



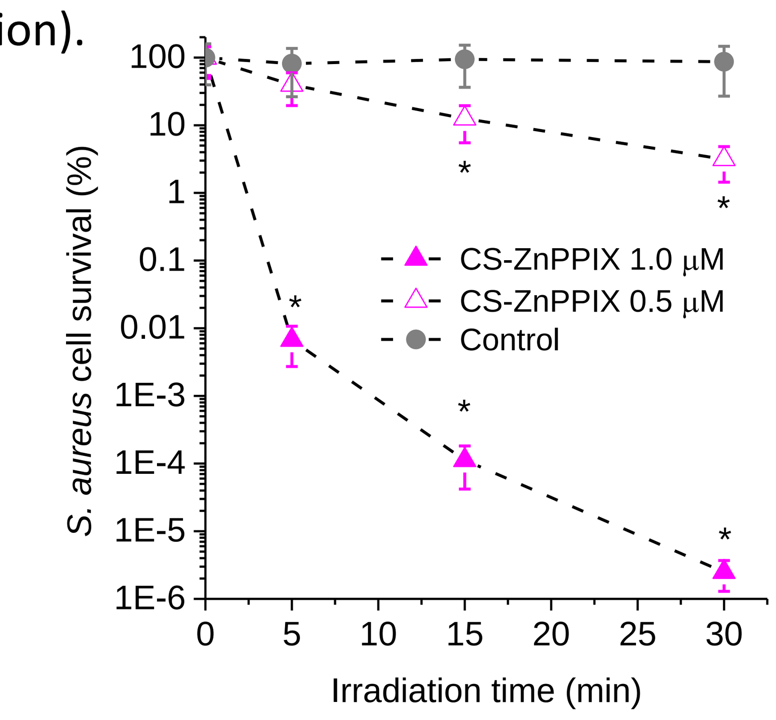
(A) Absorption and (B) emission spectra (λ_{exc}=550 nm) of CS-ZnPPIX, ZnPPIX and ZnTMP in DMF.



(A) Photooxidation of 9,10-dimethylanthracene (DMA) and (B) photoreduction of nitrotetrazolium (NBT) in DMF (λ_{irr} = 550 nm, Δ_{time} = 60 s).

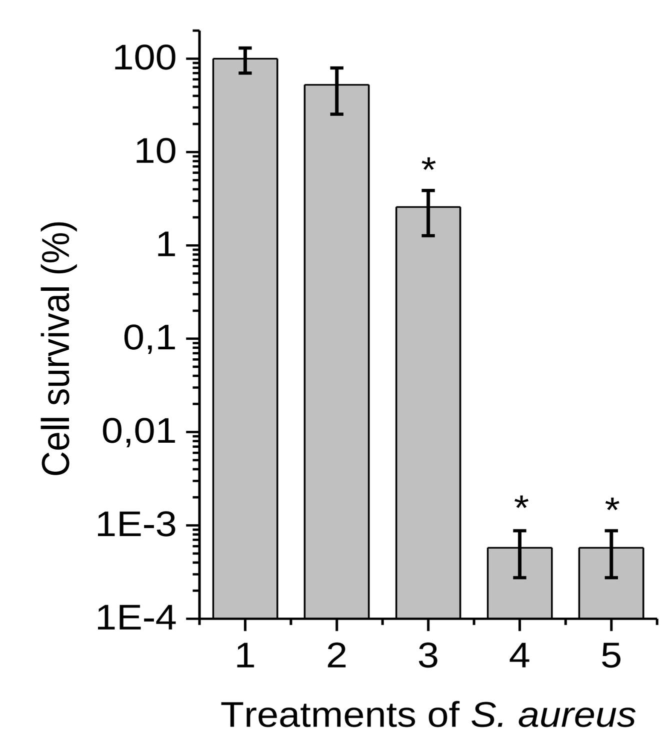
RESULTS & DISCUSSION

Then, in vitro, 1 μM CS-ZnPPIX with 30 min white light irradiation eradicated Staphylococcus aureus (>7 log, 99.9999% reduction).



S. aureus cell viability (~10^8 CFU/mL) after incubation with CS-ZnPPIX.

Following, the effectiveness of PDI was evaluated to reduce *S. aureus* in food packaging. CS-ZnPPIX decontaminated polyethylene terephthalate (PET), expanded polystyrene (EPS), glass, and aluminum surfaces, achieving over a 5 log reduction (99.9998%) in bacterial survival, as shown in the following graph:

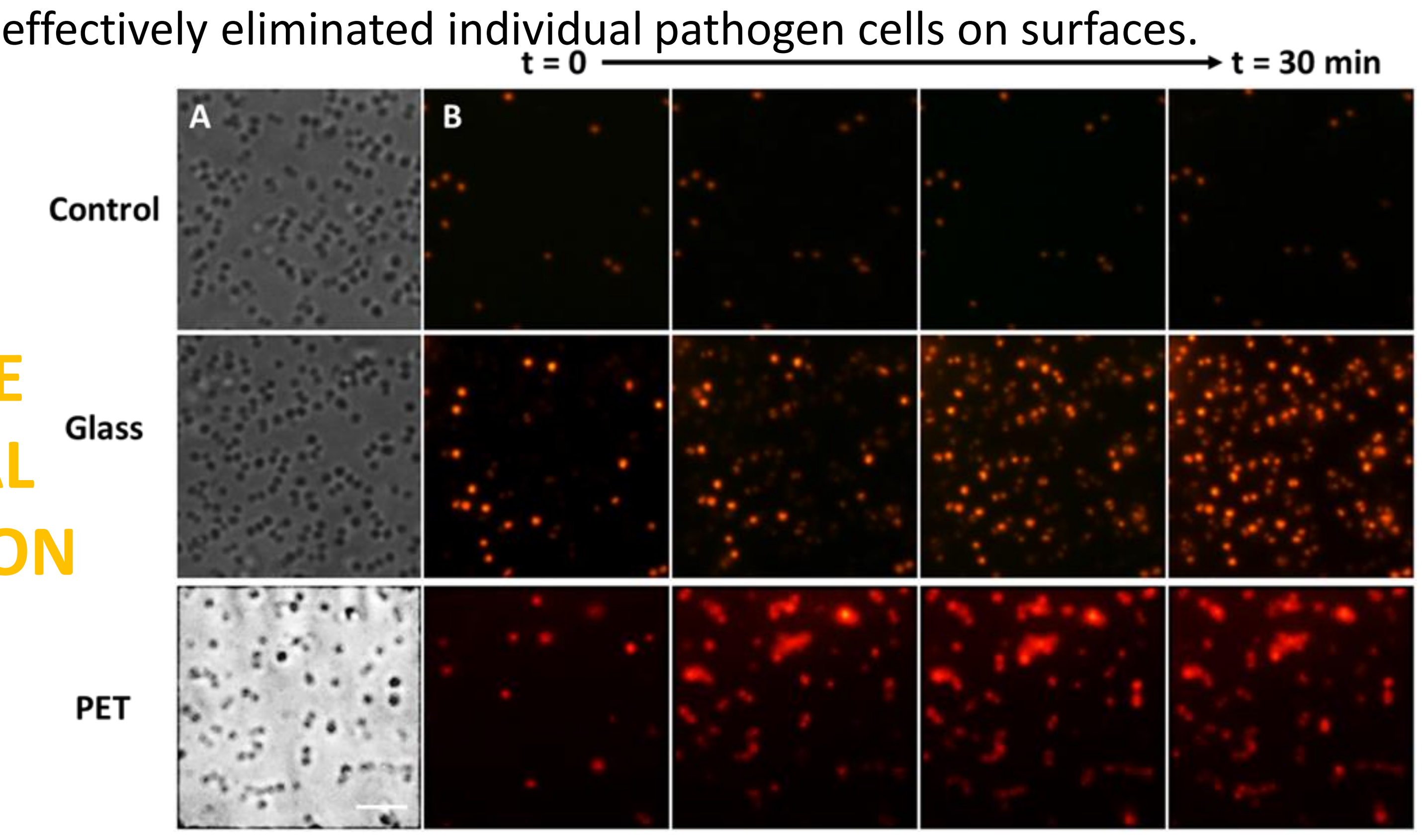


Decontamination of EPS soaked with a cell suspension (100 μL, ~10^5 CFU/mL) of *S. aureus* and treated with 0.54 nmol of CS-ZnPPIX.

1) Cells in the dark
2) Cells on packaging in the dark
3) Cells on packaging treated in the dark
4) Cells on packaging treated and irradiated for 15 min
5) Cells on packaging treated and irradiated for 30 min

Finally, CS-ZnPPIX effectively eliminated individual pathogen cells on surfaces.

EFFECTIVE BACTERIAL ERADICATION



Microscopy images of *S. aureus* incubated with 5 μM CS-ZnPPIX.

CONCLUSION

The ZnPPIX units can be activated by white light to produce ROS-based cytotoxic species. Experiments conducted on *S. aureus* cell suspensions demonstrated that the conjugate exhibited remarkable bactericidal activity. Therefore, CS-ZnPPIX conjugate demonstrates promising properties for decontaminating packaging, achieving aseptic packaging materials, and aiding in food preservation.

FUTURE WORK / REFERENCES

[1] Baigorria, E. *et al. Eur. Polym. J.* **2020**, *134*, 109816.
[2] Santamarina, S. *et al. Polymers* **2022**, *14*, 4936.

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