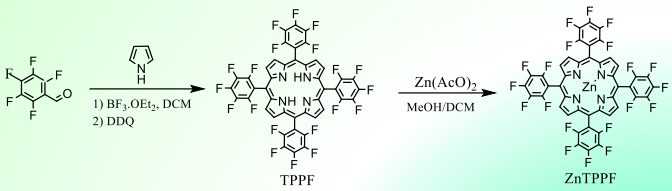
Synthesis of cationic polymers based on porphyrins for photoinactivation of bacteria

Sofía C. Santamarina, Daniel A. Heredia, Andrés M. Durantini and Edgardo N. Durantini

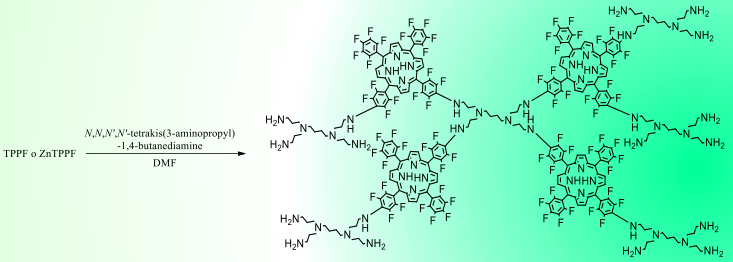
[1]IDAS-CONICET, Departamento de Química, Facultad de Ciencias Exactas, Físico-Químicas y Naturales, Universidad Nacional de Río Cuarto, Ruta Nacional 36 Km 601, X5804BYA Río Cuarto, Córdoba, Argentina.

In this work, 5,10,15,20-tetrakis(pentafluorophenyl)porphyrin ($TPPF_{20}$) was synthesized from the condensation between pentafluorobenzaldehyde and pyrrole catalyzed by $BF_3{\cdot}OEt_2$ in dichloromethane [1]. Subsequent oxidation reaction with 2,3-dichloro-5,6-dicyano-*p*-benzoquinone afforded $TPPF_{20}$ in 38% yield. This porphyrin is a versatile template to develop more elaborate photodynamic compounds. $TPPF_{20}$ can be modified by nucleophilic aromatic substitution (S_NAr) with the displacement of the four *para*-fluoro atoms [2]. This porphyrin was metaled with Zn(II) acetate in DCM/methanol to produce the complex $ZnTPPF_{20}$ in 98% yield. After that, $TPPF_{20}$ and $ZnTPPF_{20}$ were reacted with *N*,*N*,*N*′,*N*′-tetrakis(3-aminopropyl)-1,4-butanediamine as the dendrimeric structure by S_NAr to obtain two polymers, $PTPPF_{16}$ and $PZnTPPF_{16}$, respectively. The reactions were carried out in *N*,*N*-dimethylformamide at room temperature for 44 h, followed by heating at 80 °C for 4 h. This approach produces the polymers in 100% conversion. The polymers were purified by precipitation in water and washing the solid with petroleum ether. The UV-visible absorption spectra of $PTPPF_{16}$ and $PZnTPPF_{16}$ showed the Soret and Q bands of both polymers red-shifted by about 15 nm compared to those of the corresponding monomers, $TPPF_{20}$ and $ZnTPPF_{20}$. Also, the polymers exhibited the two red emission bands, characteristic of porphyrins. Furthermore, these polymers were able to produce reactive oxygen species, such as singlet molecular oxygen and superoxide radical anion. Therefore, $PTPPF_{16}$ and $PZnTPPF_{16}$ are potential photodynamic materials to eliminate pathogens.

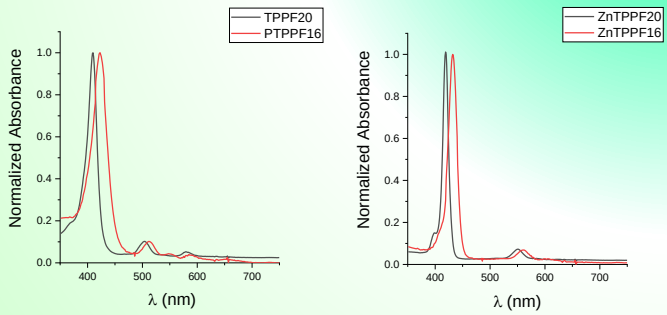
Synthesis of porphyrins

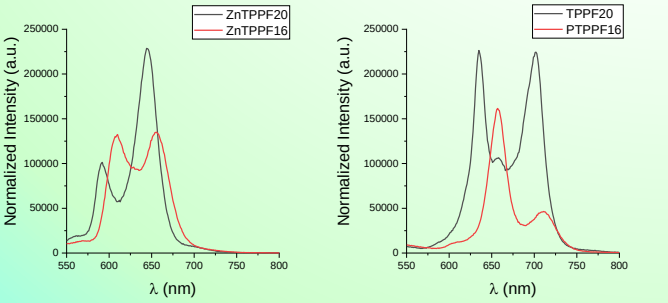


Synthesis of polymer

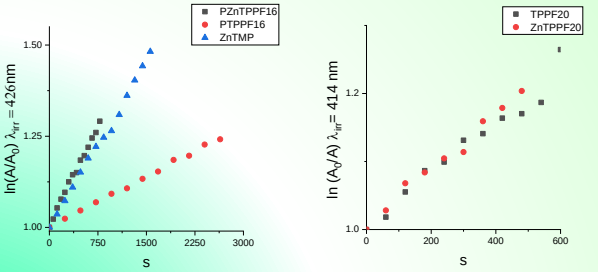


Photophysical characterization



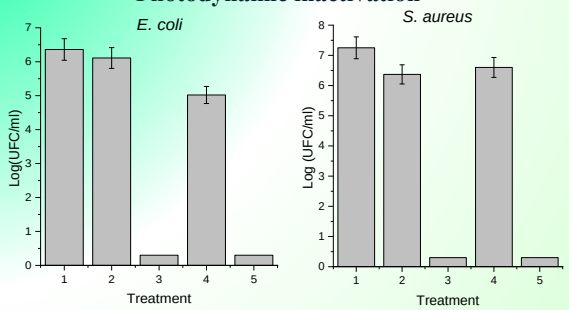


Photodynamic properties



	λ_{max} (nm)	Φ_{Δ}^{DMF}	λ_{max}^{Em} (nm)	Φ_{F}^{DMF}
ZnTMP	426	0.73	607	0.049
$TPPF_{20}$	410	0,80	634	0.039
$ZnTPPF_{20}$	419	0,81	644	0.027
$PTFFP_{16}$	423	0,22	658	0.018
$PZnTPPF_{16}$	433	0.86	608	0.025

Photodynamic inactivation



Treatments: 1) Control, 2) $PZnTPPF_{16}$ in dark, 3) $PZnTPPF_{16}$ with light, 4) $PTPPF_{16}$ in dark, and 5) $PTPPF_{16}$ with light. (*S. aureus* and *E. coli* were irradiated for 15 min and 30 min with white light (90 mW/cm^2), respectively)

Conclusions

The synthesis of the corresponding porphyrins, and their subsequent polymerization were carried out in a fast and simple way by S_NAr. The polypropylene imine crosslinked porphyrin monomers formed a polymeric structure and retained spectroscopic absorption and fluorescence spectroscopic properties. Through photodynamic studies it was demonstrated that the polymers possess the ability to produce singlet molecular oxygen. According to these results, the polymers have potential applications for the PDI of bacteria, achieving a complete eradication of *S. aureus* after 15 min of irradiation, and after 30 min in the case of *E. coli*.

References

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[2] D. A. Heredia, S. R. Martínez, A. M. Durantini, M. E. Pérez, M. I. Mangione, J. E. Durantini, M. A. Gervaldo, L. A. Otero, E. N. Durantini, ACS Appl. Mater. Interfaces 2019, 11, 27574-27587.