

Fabrication of Hybrid Polycaprolactone Nanofibers Enriched with Curcumin, Zinc Oxide, and Titanium Dioxide Nanoparticles for Wound Dressing Applications

Yeong Han Lee¹, Yun Khoon Liew², Wei Meng Lim³, Lai Chun Wong⁴, Yoon Yee Then⁴

¹School of Postgraduate Studies International Medical University, Kuala Lumpur, Malaysia

²Department of Life Sciences, School of Pharmacy, International Medical University, Kuala Lumpur, Malaysia

³School of Pharmacy, Monash University Malaysia, Selangor, Malaysia

⁴Department of Pharmaceutical Chemistry, School of Pharmacy, International Medical University, Kuala Lumpur, Malaysia

Abstract

Curcumin is a naturally occurring substance that has been used therapeutically in various regions worldwide for centuries. However, its drawbacks limit its bioactivity, including limited bioavailability, water insolubility, chemical instability, and extensive metabolism. To overcome these restrictions, the electrospinning method was employed to generate nanofibers made of polycaprolactone (PCL), curcumin (Cur), titanium dioxide (TiO₂), and zinc oxide (ZnO) in this study. The release of curcumin was investigated, and the shape and physical properties of nanofibers were compared to those of pristine PCL. In addition, the antibacterial and antibiofilm abilities of the nanofibers were assessed against two typically linked opportunistic pathogens, *Pseudomonas aeruginosa* and *Staphylococcus aureus*.

Introduction

Nanofibers are fibers with diameters below 1000 nanometers. They can be produced from electrospinning technology by applying high voltage electric force to the polymer solution on needle tips and collector. Electrospun nanofibers used as wound dressing can help to promote cell growth¹. It can be mixed with some antibacterial agents to enhance the therapeutic effect of wound healing². The addition of composite of curcumin-metal oxide nanoparticles in nanofibers could enhance the properties of nanofibers, such as physicochemical, antibacterial, and wound healing.

Methodology

The polymer solutions were prepared by dissolving 12 wt% of PCL in chloroform and dimethylformamide (6:4). The various amounts of Cur, TiO₂, and ZnO as shown in Table 1, were added into the polymer solution. The nanofibers were produced from the polymer solutions via electrospinning with a working distance of 20 cm, applied voltage of 15 kV and a flow rate of 0.5 mL/h. The physicochemical, antibacterial, and antibiofilm properties of Cur/TiO₂/ZnO-loaded PCL nanofibers were analysed.



Table 1 Formulation of electrospun PCL nanofibers loaded with Cur, TiO₂ and ZnO

Sample	CUR (w/w%)	ZnO (w/w%)	TiO ₂ (w/w%)
1CUR-TiO ₂ /ZnO/PCL	1	1	1
3CUR-TiO ₂ /ZnO/PCL	3	1	1
5CUR-TiO ₂ /ZnO/PCL	5	1	1
7CUR-TiO ₂ /ZnO/PCL	7	1	1
10CUR-TiO ₂ /ZnO/PCL	10	1	1
15CUR-TiO ₂ /ZnO/PCL	15	1	1
PCL (control)	-	-	-

*w/w% = weight-to-weight ratio

Results

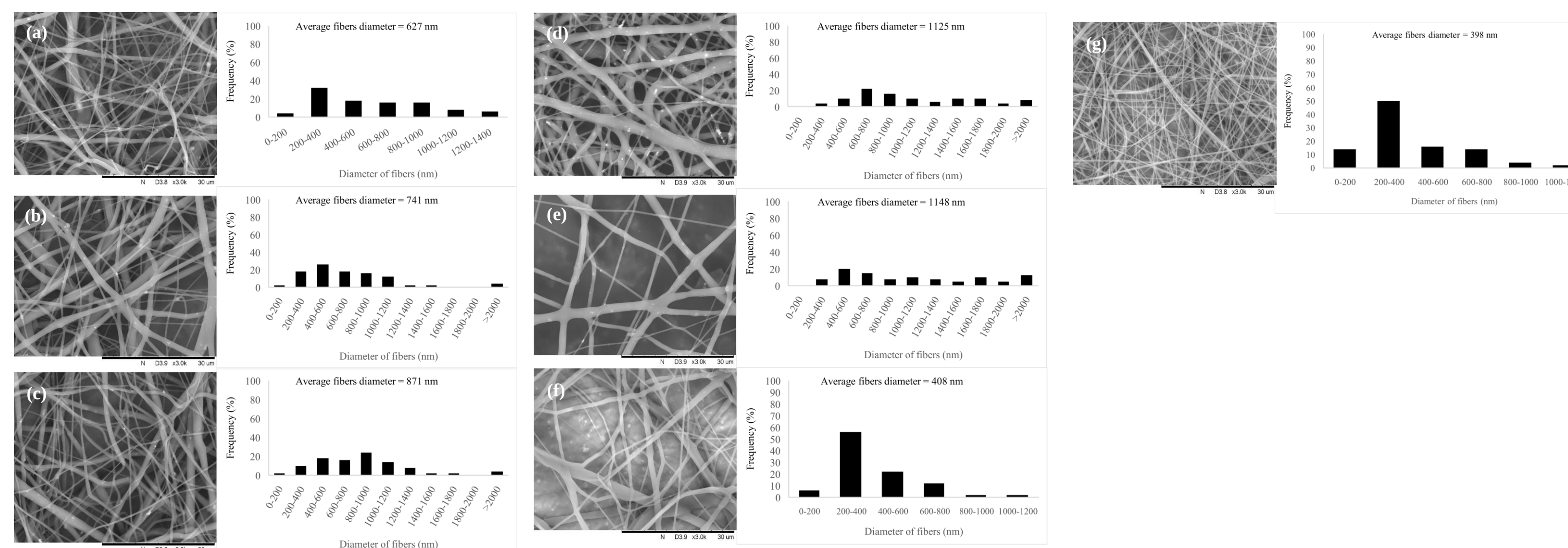


Figure 1 SEM and the histogram obtained from measuring fibre diameters from each nanofiber sample. (a) 1CUR-TiO₂/ZnO/PCL ; (b) 3CUR-TiO₂/ZnO/PCL ; (c) 5CUR-TiO₂/ZnO/PCL ; (d) 7CUR-TiO₂/ZnO/PCL ; (e) 10CUR-TiO₂/ZnO/PCL ; (f) 15CUR-TiO₂/ZnO/PCL ; (g) PCL

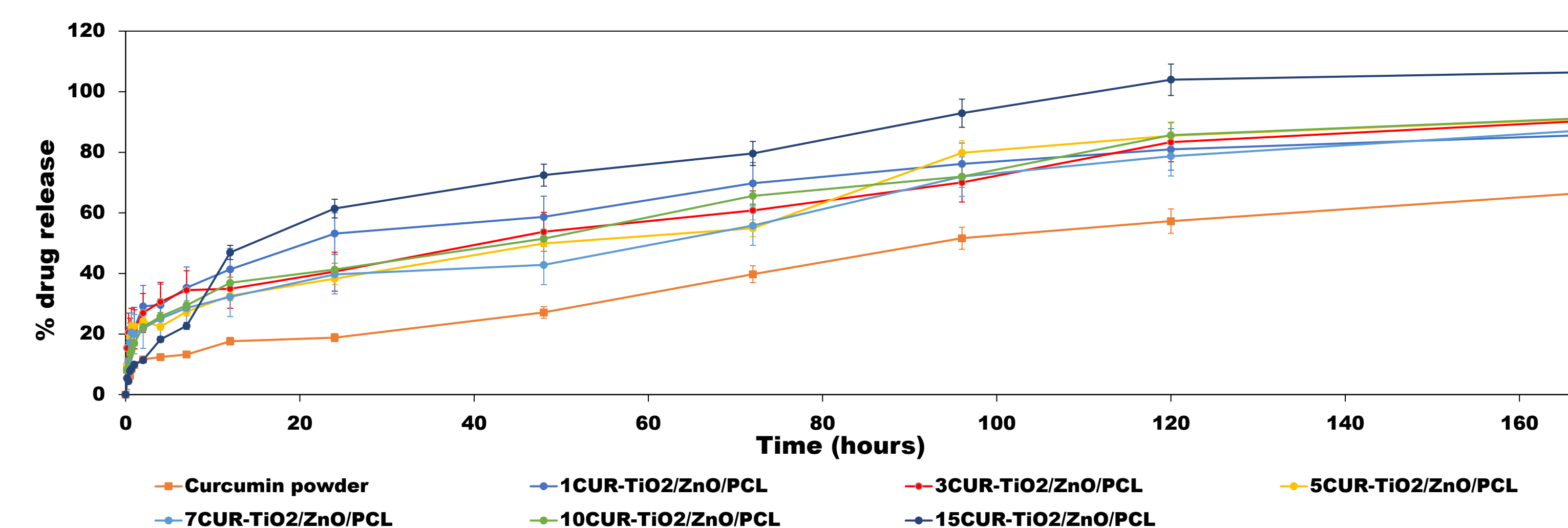


Figure 2 *In-vitro* curcumin release study of CUR-TiO₂/ZnO/PCL nanofibers with different concentrations of curcumin.

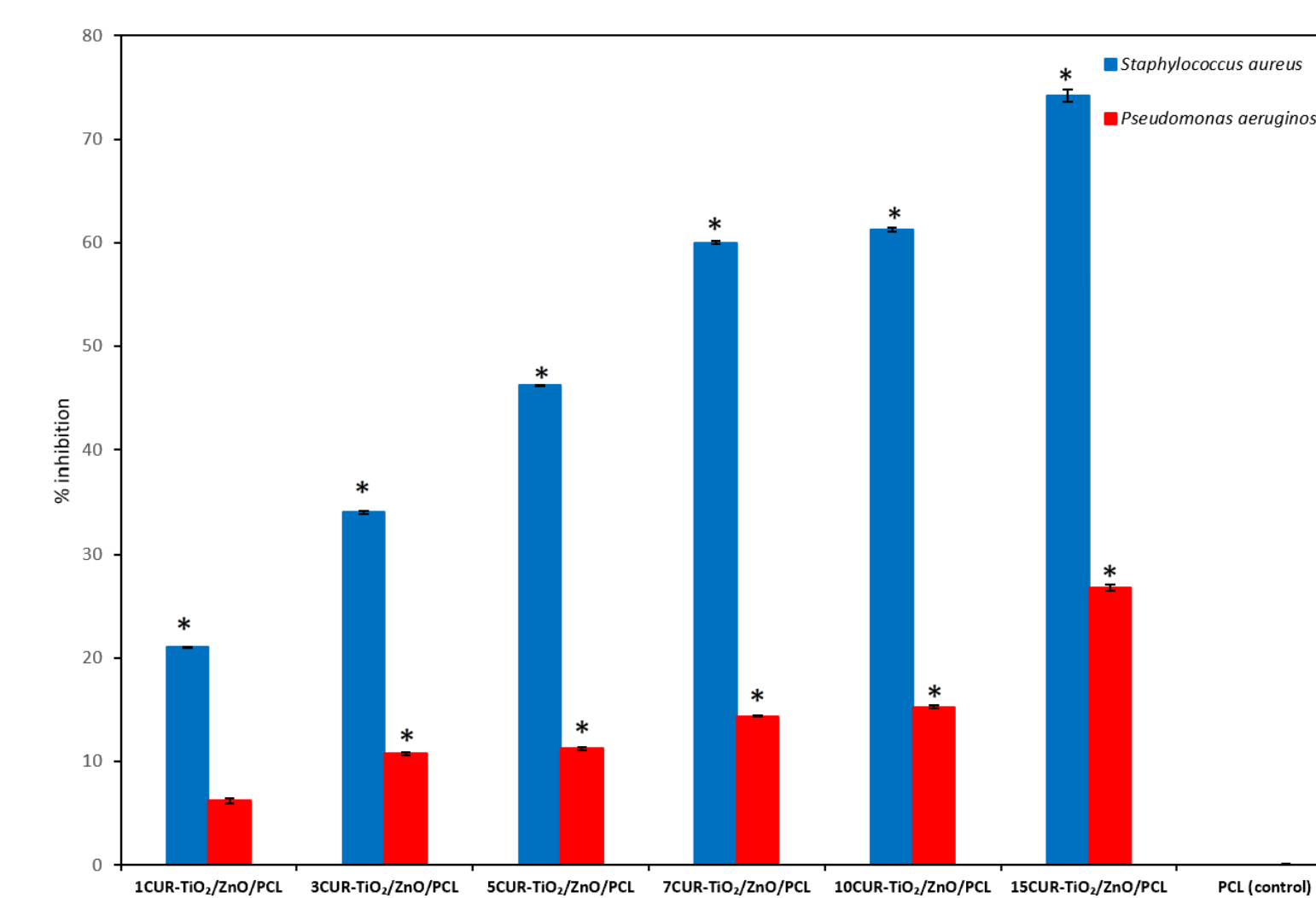


Figure 3 Inhibition of the nanofibrous sample against planktonic cells of *S. aureus* and *P. aeruginosa* respectively. * symbol indicates there is a significant difference ($p < 0.05$) with the control group (PCL nanofiber).

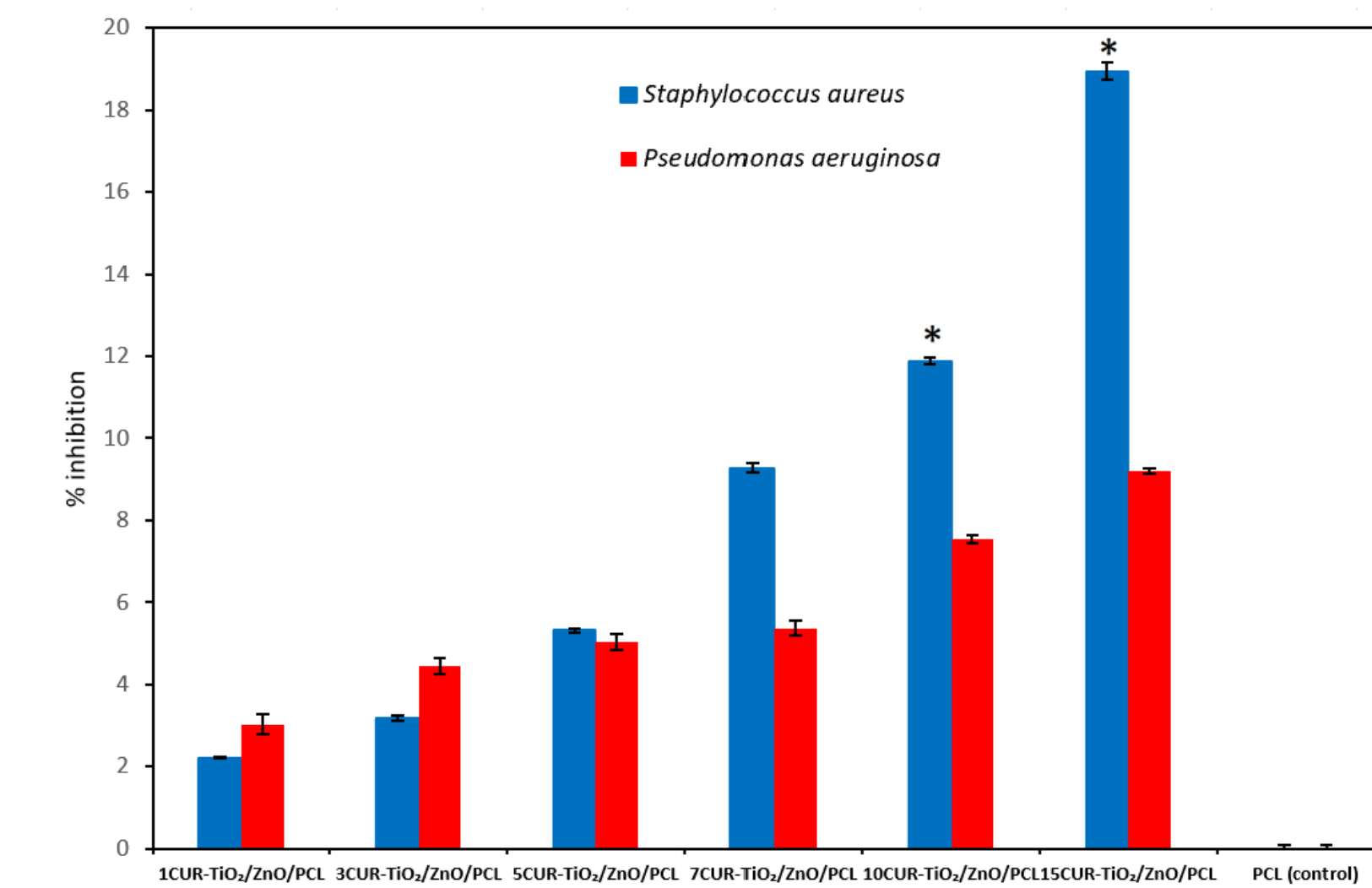


Figure 4 Inhibition of the nanofibrous sample against biofilm formed by *S. aureus* and *P. aeruginosa* respectively. * symbol indicates there is a significant difference ($p < 0.05$) with the control group (PCL nanofiber).

Conclusion

- The resultant nanofibers possessed randomly oriented and spherical fibers devoid of flaws.
- In-vitro* curcumin release study showed the burst release of the curcumin at the beginning of time, followed by sustained release from nanofibers.
- Cur/TiO₂/ZnO-loaded PCL nanofibers can suppress the formation and activity of biofilms related to both *Pseudomonas aeruginosa* and *Staphylococcus aureus*
- Increasing curcumin content in electrospun Cur/TiO₂/ZnO-loaded PCL nanofibers can increase the average diameter of nanofibers, increase the release rate of curcumin from nanofibers and enhance antibacterial and antibiofilm properties.

References

- Gao C, Zhang L, Wang J, Jin M, Tang Q, Chen Z, *et al.* Electrospun nanofibers promote wound healing: theories, techniques, and perspectives. J Mater Chem B 2021;9:3106–30.
- Mei L, Fan R, Li X, Wang Y, Han B, Gu Y, *et al.* Nanofibers for improving the wound repair process: the combination of a grafted chitosan and an antioxidant agent. Polym Chem 2017;8:1664–71.