Electrospinning of Chitosan/Poly(ethylene oxide) Nanofibers for Antimicrobial Applications in Biomedical and Food

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Abstract

Nanofibers have garnered significant attention due to their excellent antibacterial properties and low cytotoxicity. Chitosan (CS), known for its biocompatibility, non-toxicity, and inherent antimicrobial activity, has been widely utilized in medicine and food-related applications. However, the protonation of chitosan in acidic solvents hinders its electrospinning process. To overcome this challenge, poly(ethylene oxide) (PEO) was introduced to improve the spinnability of chitosan. This study successfully fabricated CS/PEO nanofibers by optimizing polymer concentration and tuning electrospinning parameters such as voltage and flow rate. The nanofibers were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), and Fourier-transform infrared spectroscopy (FT-IR). Antimicrobial properties were evaluated using the colony counting method. The experimental results revealed that the optimal electrospinning conditions were achieved at a voltage of 20 kV and a flow rate of 1 mL/h. The morphology analysis confirmed the formation of uniform, defect-free nanofibers.

Additionally, incorporating chitosan significantly enhanced the antimicrobial properties, with higher chitosan weight percentages correlating positively with increased antibacterial activity. Under the optimized conditions, the CS/PEO nanofibers achieved an outstanding antibacterial efficiency of 97%. This remarkable performance is attributed to the synergistic effect of chitosan's antimicrobial activity and the structural integrity provided by PEO. These findings suggest that CS/PEO nanofibers hold significant potential for biomedical devices and food preservation applications.

Introduction

Chitosan (CS), a biocompatible and antibacterial polymer, was blended with polyethylene oxide (PEO) to fabricate nanofibers via electrospinning. By adjusting polymer ratios and voltage, nanofiber morphology and antibacterial properties were optimized. SEM, XRD, and ATR-FTIR were used to analyze structure and composition. Antibacterial tests, including colony counting, MIC, and inhibition zone assays, showed that optimized fibers reduced bacterial viability to 3.69% within 30 minutes. The results demonstrate the strong potential of CS/PEO nanofibers for antimicrobial applications.

Experimental

1. Fabrication of Chitosan/PEO Fibers

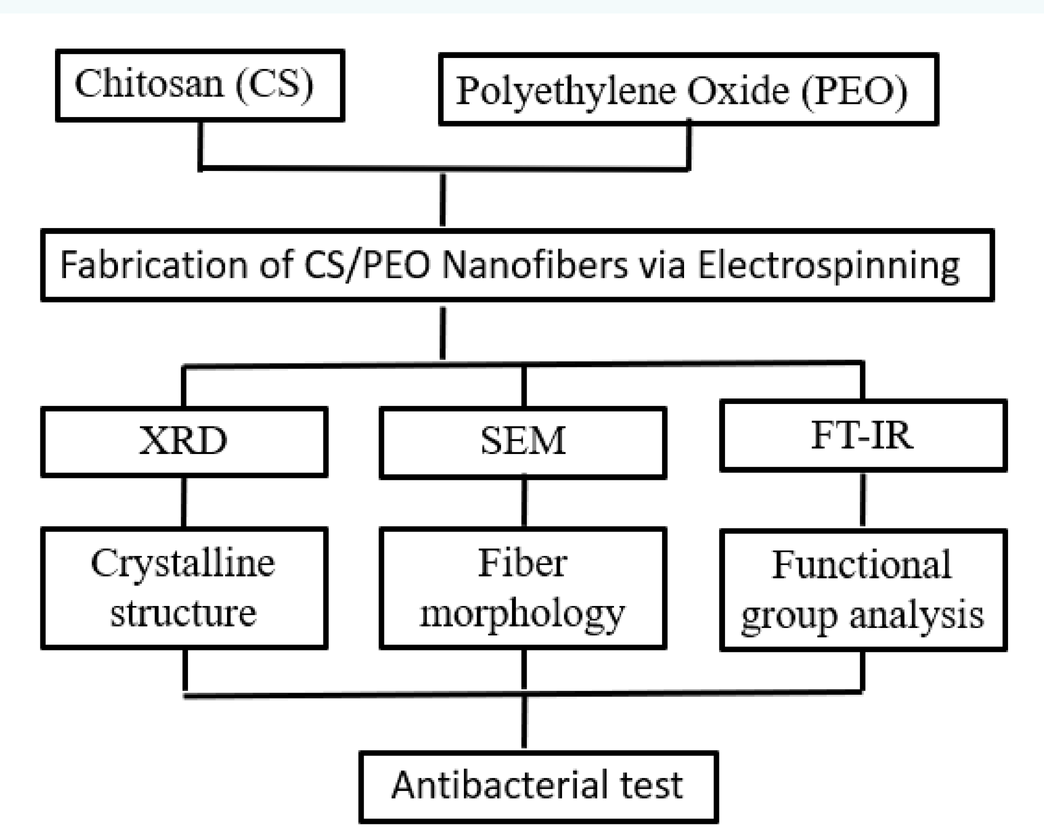

Fig. 1. Schematic diagram of the fabrication of chitosan/PEO fibers.

2. Antibacterial Study of Chitosan/PEO Composites

Chitosan fibers were assessed for antibacterial activity using a colony counting assay. A 1.5 mL suspension of *E. coli* (10^5 CFU/mL) was mixed with the sample, left to react briefly, and 150 μL of the mixture was spread onto agar plates. After incubation at 37 ˚C for 18 hours, colony numbers were recorded.

Results and Discussion

1. XRD Analysis of Crystalline Structure

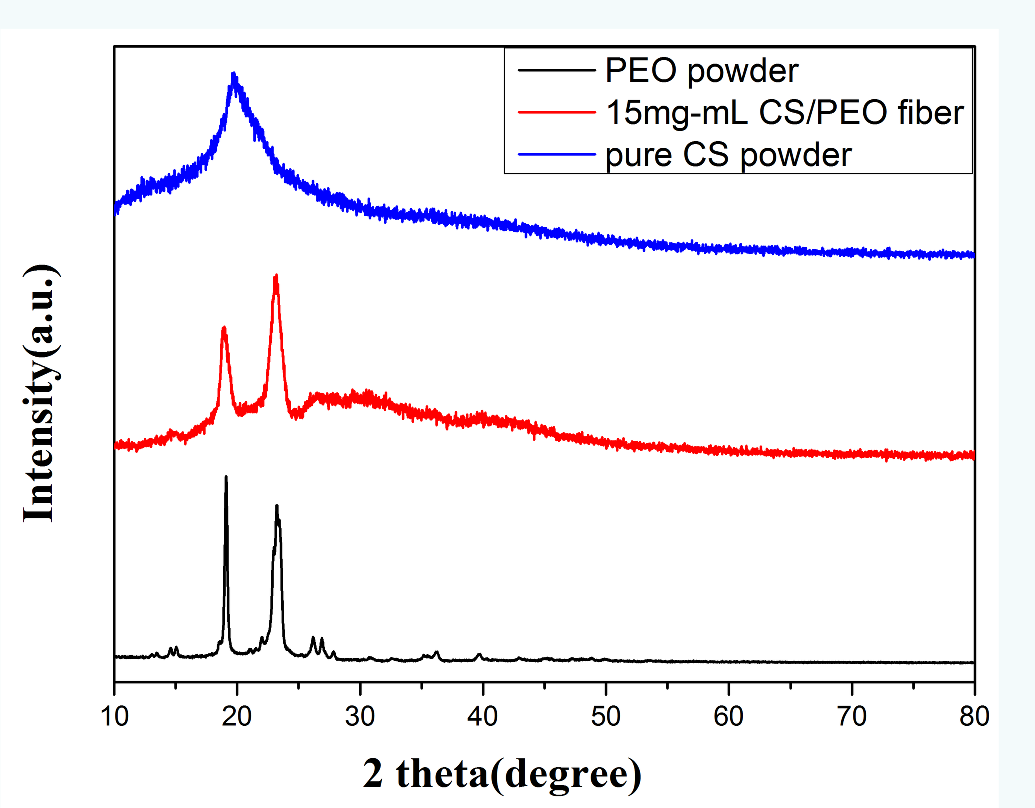

Fig. 2. XRD patterns of CS/PEO fibers, CS powder, and PEO powder.

2. Morphological Analysis of Electrospun Fibers by SEMSEM

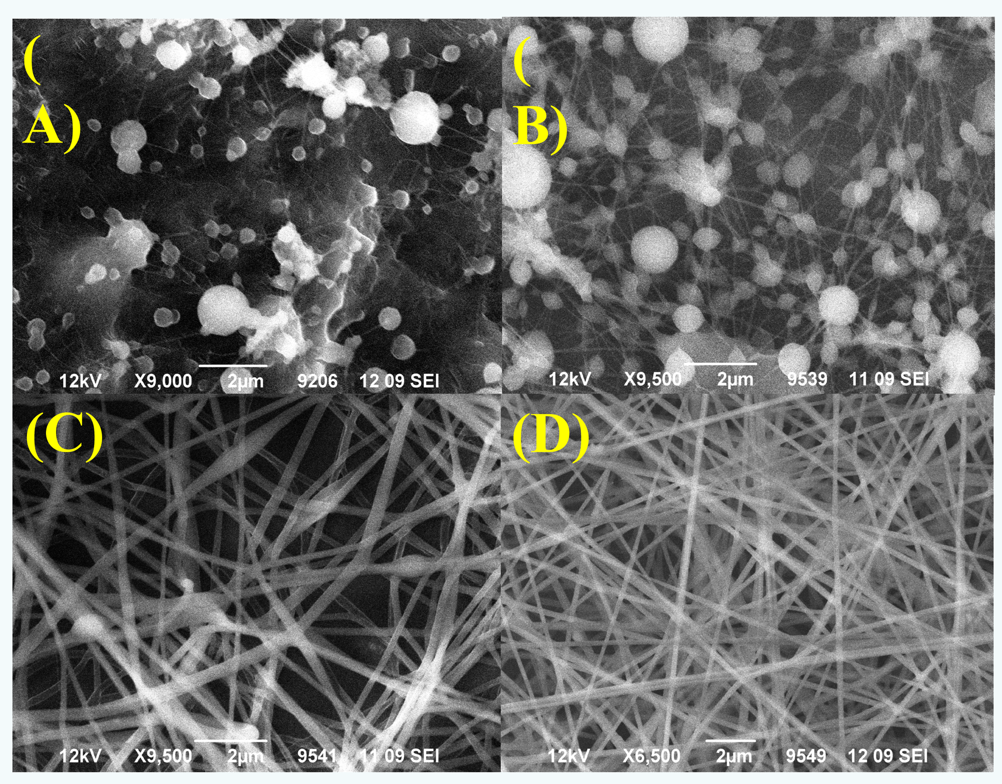

Fig. 3. SEM images of PEO/CS fibers with varying PEO content:(A) 5%, (B) 8%, (C) 10%, (D) 12% .

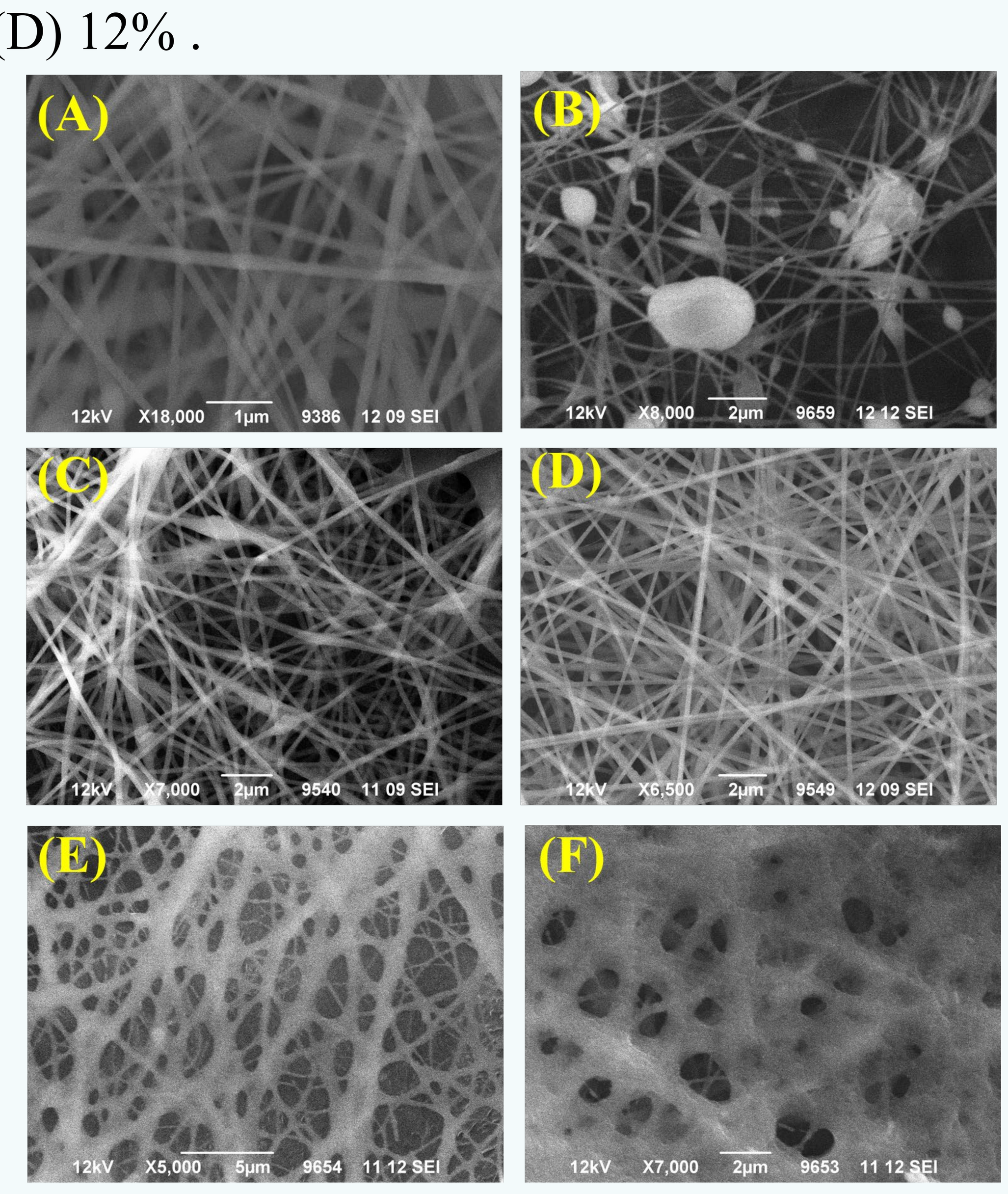

Fig. 4. SEM images of fibers with varying CS concentrations: (A) 12% PEO , (B) 5 mg/mL CS/PEO , (C) 10 mg/mL CS/PEO, (D) 15 mg/mL, (E) 20 mg/mL, (F) 25 mg/mL.

3. Functional Group Analysis by ATR-FTIR

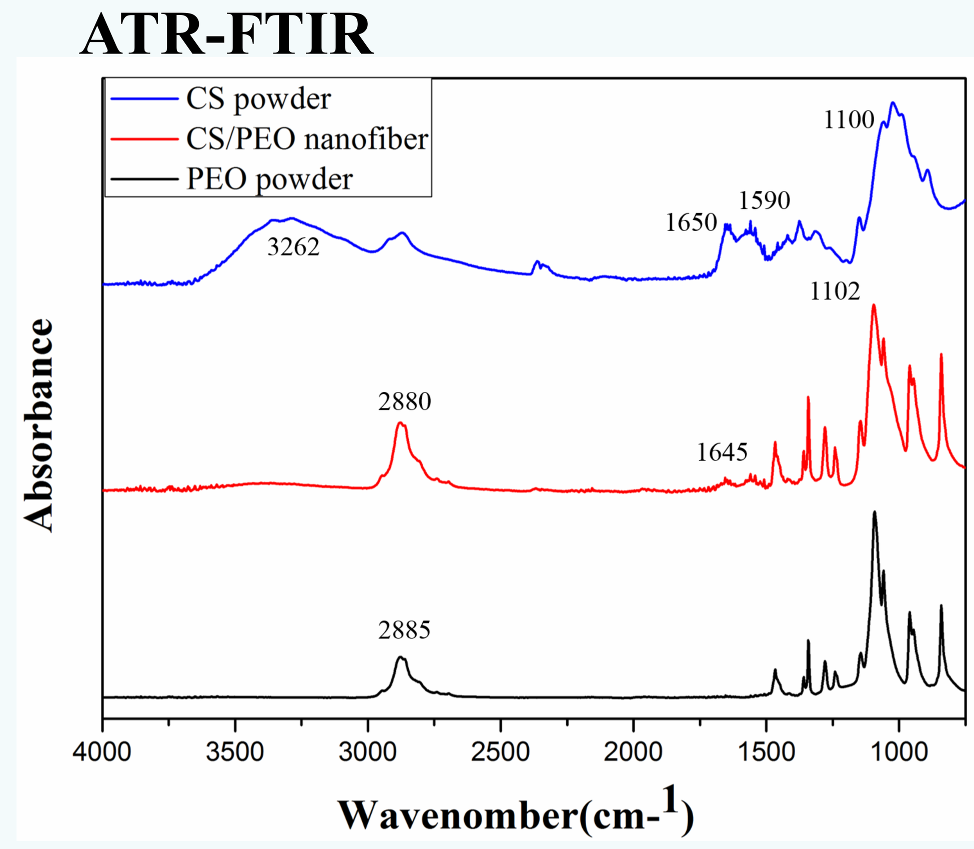

Fig. 5. ATR-FTIR spectra of CS/PEO fibers, CS powder, and PEO powder.

4. Evaluation of Antibacterial Activity

(1). Colony Counting

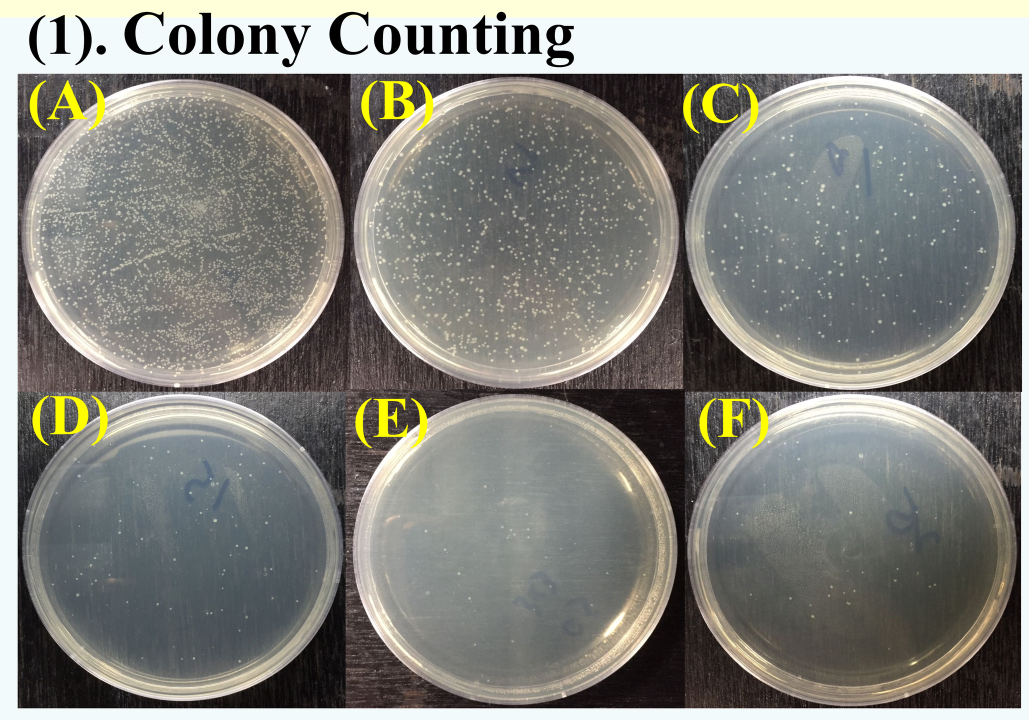

Fig. 6. Antibacterial activity of CS/PEO fibers at different concentrations: (A) Blank, (B) 5 mg/mL, (C) 10 mg/mL, (D) 15 mg/mL, (E) 20 mg/mL, (F) 25 mg/mL.

(2). Minimum Inhibitory Concentration (MIC)

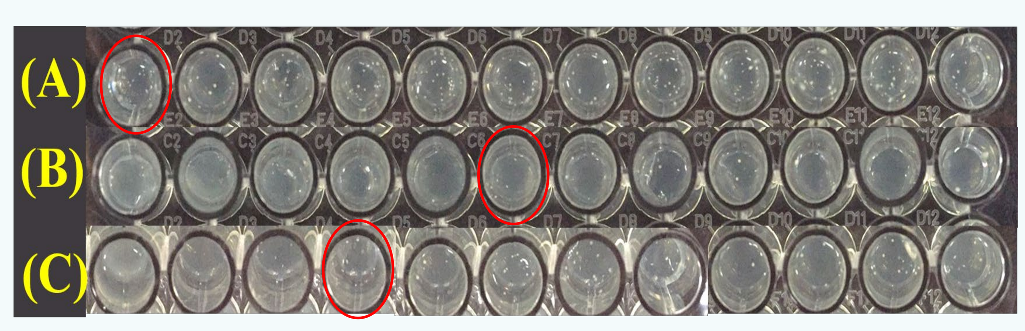

Fig. 7. Antibacterial activity of different fiber samples: (A) PEO fibers, (B) CS/PEO fibers at 15 mg/mL chitosan concentration, and (C) chitosan powder.

3. Inhibition zone

Table 1. Inhibition zone diameters of CS/RGO composites synthesized at various microwave temperatures against *Escherichia coli*.

Sample	200°C	180°C	160°C	140°C
抑菌圈大小	1 ± 0.3 mm	1.2 ± 0.2 mm	3 ± 0.2 mm	0.7± 0.1 mm

Conclusion

Electrospun chitosan/PEO nanofibers were characterized by XRD, ATR-FTIR, and SEM. The 15 mg/mL CS/PEO formulation produced uniform fibers without bead defects and showed strong antibacterial activity. These results highlight the material's potential for biomedical applications.

Reference

1. Deng, L.; Taxipalati, M.; Zhang, A.; Que, F.; Wei, H.; Feng, F.; Zhang, H. *J. Agric. Food Chem.* **2018**, *66*, 6219−6226.
2. Arkoun, M.; Daigle, F.; Heuzey, M. C.; Ajji, A. *Molecules.* **2017**, *22*, 585-602.
3. Kuntzlera, S. G.; Costa, J. A. V.; Moraisa, M. G. *Int. J. Biol. Macromol.* **2018**, *117*, 800-806.
4. Wardhani, R. A. K.; Asri, L.; Nasir, M.; Purwasasmita, B. S. *JMEST.* **2019**, *3*, 1-7.