

Supplementary Information

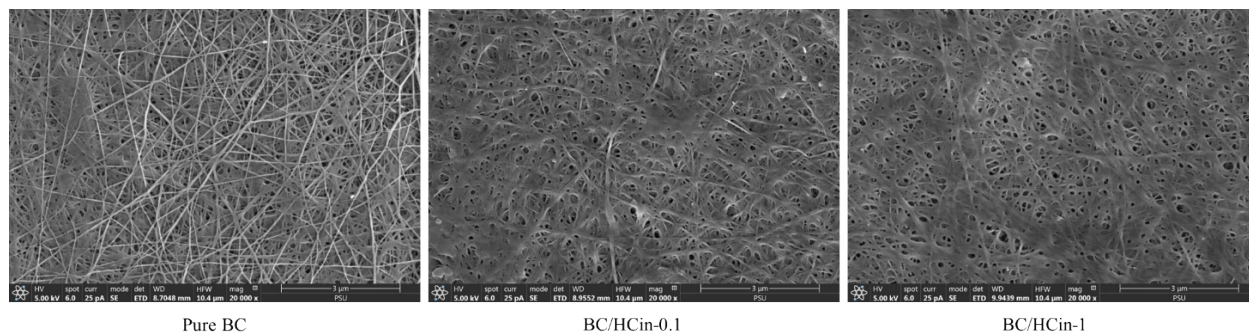


Fig. S1 Surface morphology comparison of pure BC, BC/HCl-0.1, and BC/HCl-1 at the same magnification (20,000 $\times$) reveals a progressive reduction in fibril size with increasing HC content. Conversely, membrane pores become more clearly defined as the HC content increases.

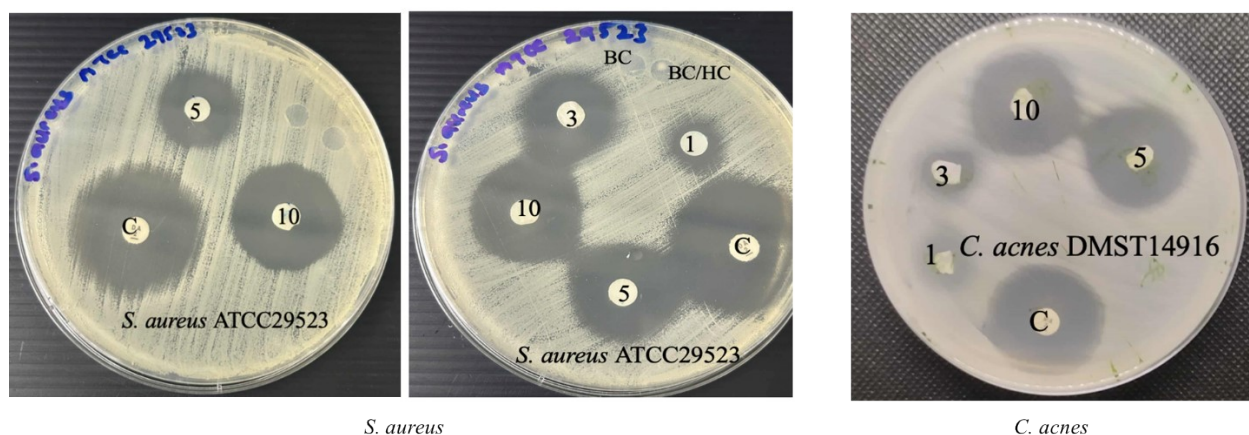


Fig. S2 Disc diffusion assay results show clear zones of inhibition (ZOI) for BC, BC/HC, BC/HC/TTO-1, BC/HC/TTO-3, BC/HC/TTO-5, and BC/HC/TTO-10 against *Staphylococcus aureus* and *Cutibacterium acnes*.

Table S1 Zone of inhibition (ZOI) for BC, BC/HC, BC/HC/TTO-1, BC/HC/TTO-3, BC/HC/TTO-5, BC/HC/TTO-10, and clindamycin (CLN, positive control) against *Staphylococcus aureus* and *Cutibacterium acnes*

Sample	ZOI (mm)	
	<i>S. aureus</i>	<i>C. acnes</i>
BC	0.00 ± 0.00	0.00 ± 0.00
BC/HC	0.00 ± 0.00	0.00 ± 0.00
BC/HC/TTO-1	11.47 ± 0.65	7.75 ± 0.32
BC/HC/TTO-3	16.48 ± 0.60	10.78 ± 0.21
BC/HC/TTO-5	20.85 ± 0.57	14.96 ± 0.31
BC/HC/TTO-10	25.70 ± 0.19	23.20 ± 0.28
CLN (control)	27.85 ± 0.39	25.79 ± 0.28

Table S2 Time-kill kinetics of BC/HC composites loaded with TTO at different amounts against *Staphylococcus aureus*. TTO incorporation into BC/HC composites enhances its antibacterial efficacy in a dose-dependent manner, with higher TTO loadings providing faster and more effective bactericidal activity.

Time (h)	Log ₁₀ CFU/mL of <i>S. aureus</i>				
	BC	BC/HC/TTO-1	BC/HC/TTO-3	BC/HC/TTO-5	BC/HC/TTO-10
0	5.880±0.06	5.834±0.14	5.769±0.08	5.728±0.09	5.655±0.04
1	6.081±0.06	5.757±0.07	5.525±0.06	5.486±0.04	3.996±0.07
2	6.819±0.03	5.646±0.02	4.643±0.01	4.674±0.19	0.000±0.00*
3	7.612±0.07	5.490±0.04	3.229±0.04	0.000±0.00*	0.000±0.00*
6	10.215±0.01	5.226±0.08	0.000±0.00*	0.000±0.00*	0.000±0.00*
9	10.311±0.02	4.674±0.04	0.000±0.00*	0.000±0.00*	0.000±0.00*
12	10.337±0.03	4.054±0.02	0.000±0.00*	0.000±0.00*	0.000±0.00*
24	12.086±0.04	0.000±0.00	0.000±0.00*	0.000±0.00*	0.000±0.00*
48	5.880±0.06	0.000±0.00	0.000±0.00*	0.000±0.00*	0.000±0.00*

* No bacterial growth detected (0 CFU).

Table S3 Time-kill kinetics of BC/HC composites loaded with TTO at different amounts against *Cutibacterium acnes*. TTO incorporation into BC/HC composites enhances its antibacterial efficacy in a dose-dependent manner, with higher TTO loadings providing faster and more effective bactericidal activity.

Time (h)	Log ₁₀ CFU/mL of <i>C. acnes</i>				
	BC	BC/HC/TTO-1	BC/HC/TTO-3	BC/HC/TTO-5	BC/HC/TTO-10
0	5.869±0.05	5.880±0.03	5.876±0.04	5.756±0.02	5.721±0.03
1	5.923±0.04	5.604±0.04	4.896±0.10	4.516±0.06	4.356±0.09
2	5.858±0.06	5.591±0.07	4.724±0.03	4.360±0.39	2.301±0.30
3	5.956±0.04	5.547±0.04	4.318±0.01	4.155±0.04	0.000±0.00*
6	7.300±0.04	5.435±0.05	3.305±0.06	2.100±0.17	0.000±0.00*
9	7.513±0.09	4.333±0.35	2.661±0.22	0.000±0.00*	0.000±0.00*
12	7.747±0.07	4.159±0.28	0.000±0.00*	0.000±0.00*	0.000±0.00*
24	7.870±0.04	4.100±0.17	0.000±0.00*	0.000±0.00*	0.000±0.00*
48	7.940±0.06	4.000±0.01	0.000±0.00*	0.000±0.00*	0.000±0.00*

* No bacterial growth detected (0 CFU).