Supplementary Information

Sustainable bio-based active packaging films: enhancing chitosan with gallic acid-loaded nanoparticles

QiHang Bu[a,b], ZeiFeng Yue[b], ZiHan Wang[b], Ning Jiang[b,], Haibo Luo[a], RongXue Sun[b], QianYuan Liu[b], JianHua Xu[c], Cheng Wang[b,*] and JiaJun Fu[c,*]*

[a] School of Food and Pharmaceutical Engineering, Nanjing Normal University, Nanjing, 210023, PR China

[b] Institute of Agricultural Products Processing, Jiangsu Academy of Agricultural Sciences, Nanjing, 210014, PR China

[c] School of Chemical Engineering, Nanjing University of Science and Technology, Nanjing 210094, PR China

Corresponding author: E-mail address: fujiajun668@gmail.com; wangcheng@jaas.ac.cn, jaas_jiangning@163.com

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Methods

Encapsulation efficiency and drug loading efficiency

The suspension of chitosan nanoparticles loaded with gallic acid was centrifuged at 13000 r/min for 30 min. Subsequently, 3 mL of the supernatant was aspirated and its absorbance was measured at $\lambda = 269$ nm. Blank chitosan nanoparticles were used as a control. The measured absorbance values were substituted into the gallic acid standard curve to determine the concentration of gallic acid. The volume of the supernatant in the centrifuge tube was measured, and the encapsulation efficiency and drug loading efficiency were calculated by equations (1) and (2), respectively[1]:

$$\text{Encapsulation efficiency \%} = \frac{m_0 - c_0 v_0}{m_0} \times 100\% \quad (1)$$

$$\text{Drug loading efficiency \%} = \frac{m_0 - c_0 v_0}{m_1} \times 100\% \quad (2)$$

Where m_0 is the mass (g) of added gallic acid, m_1 is the mass (g) of lyophilized nanoparticles, c_0 is the concentration of gallic acid in the supernatant (μg/mL), and v_0 is the volume (mL) of the supernatant.

Fig. S1 to S2

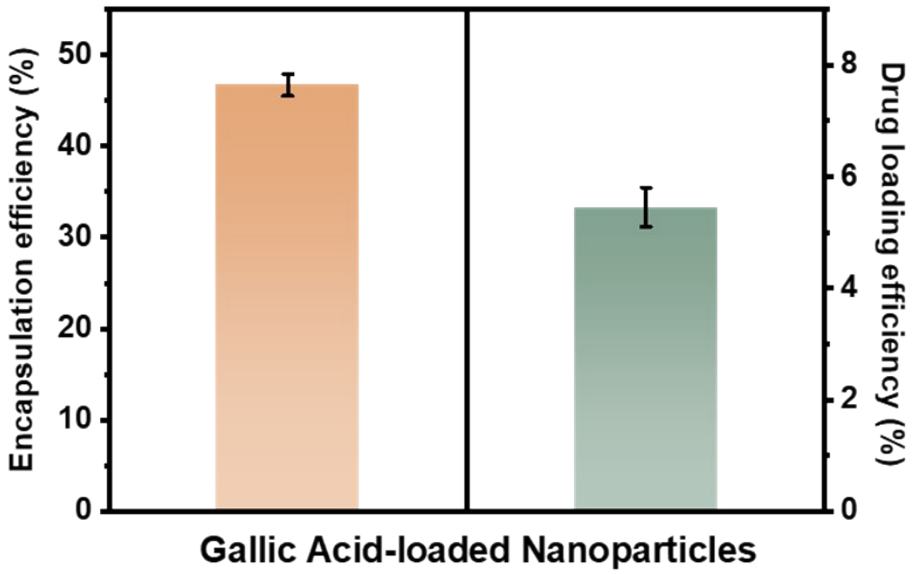

Fig. S1 The encapsulation efficiency and drug loading efficiency of the NPs.

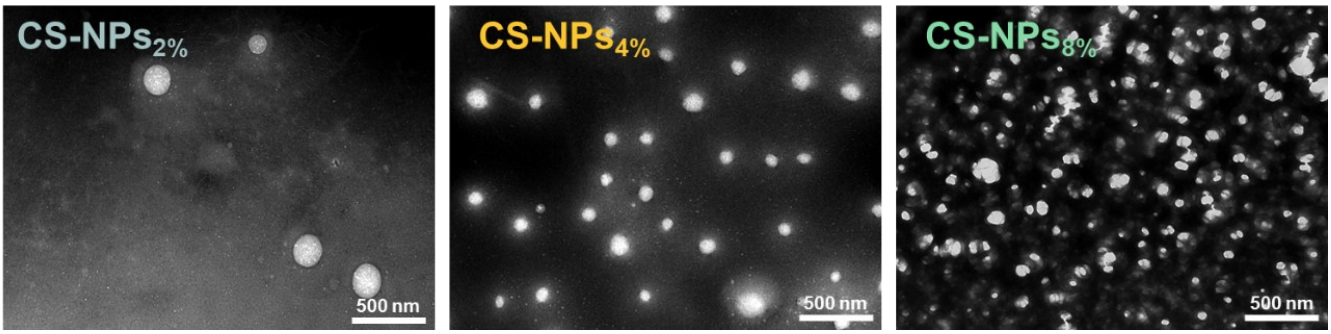

Fig. S2 Representative TEM images of the CS-NPs$_{2\%}$, CS-NPs$_{4\%}$, and CS-NPs$_{8\%}$.

When the NPs loading was less than 8 wt%, the NPs within the chitosan matrix can be uniformly dispersed, primarily due to the relatively large interparticle distance and the weak interaction forces between them. However, as the concentration of NPs increased, the distance between adjacent NPs decreased, enhancing the van der Waals forces and electrostatic interactions among them.[2] These forces could overcome the stabilizing effects of the chitosan matrix, leading to the aggregation of NPs.[3] This aggregation not only affected the mechanical properties of the composite films but also influenced their barrier and antimicrobial properties.

Reference

1. M. Ji, X. Sun, X. Guo, W. Zhu, J. Wu, L. Chen, J. Wang, M. Chen, C. Cheng and Q. Zhang, Green synthesis, characterization and in vitro release of cinnamaldehyde/sodium alginate/chitosan nanoparticles, *Food Hydrocolloid.*, 2019, **90**, 515-522.
2. P.K. Dutta, S. Tripathi, G.K. Mehrotra and J. Dutta, Perspectives for chitosan based antimicrobial films in food applications, *Food Chem.*, 2009, **114**, 1173-1182.
3. W. Zhang and W. Jiang, Antioxidant and antibacterial chitosan film with tea polyphenols-mediated green synthesis silver nanoparticle via a novel one-pot method, *Int. J. Biol. Macromol.*, 2020, **155**, 1252-1261.