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# Performance Evaluation and Application Exploration of Deacidified Chitin Nanofibril Film

CHAI Kaiyan, JI Yali\*, SUN Bin

State Key Laboratory of Advanced Fiber Materials, College of Materials Science and Engineering, Donghua University, Shanghai 201620, China

**Abstract:** In order to reduce dependence on petroleum resources, research on the application of polysaccharide-based materials has become one of the mainstream trends. The chitin nanofibril (ChNF) is a promising building block for fabricating chitin films from aqueous dispersions. In this study, tannic acid (TA) was introduced into the deacidified ChNF film as a cross-linking agent and functional additive. The structure and performance of the deacidified ChNF film were evaluated and its potentials in fruit packaging were explored. The cross-sectional morphology of the film was characterized by a scanning electron microscope, which revealed that the film was densified by deacidification, thereby improving the water resistance. The addition of TA further improved the film's wet-state mechanical property, antioxidant property, UV-shielding property and antibacterial activity, while the film preserved good optical properties. Specifically, the tensile strength of the film with TA reached ( $145.1 \pm 9.3$ ) MPa, and its free-radical scavenging rates were over 95%. Moreover, preliminary experiments demonstrated the potential of the film with TA for strawberry preservation.

**Keywords:** chitin nanofibril (ChNF); tannic acid (TA); deacidification; casting; fruit packaging

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## 0 Introduction

Chitin is a natural carbohydrate and is primarily extracted from the shells of crustaceans such as crabs and shrimp. Due to its exceptional mechanical properties, biodegradability, and biocompatibility, chitin is considered a promising bio-based material<sup>[1]</sup>. The chitin nanofibril (ChNF), which exhibits a relatively high length-to-diameter ratio, can be produced through a partial deacetylation-ultrasonication method while preserving most of the native crystalline and amorphous structure of chitin<sup>[2-3]</sup>. This makes ChNFs suitable for constructing various chitin-based materials. Studies have

demonstrated that dense ChNF films with high transparency, strength, and gas barrier properties can be fabricated by using methods such as vacuum filtration and casting<sup>[4-6]</sup>.

However, the presence of numerous hydrophilic groups, such as hydroxyl and amino groups, in the chemical structure of ChNF films and capillary action results in poor water resistance<sup>[7]</sup>. To enhance hydrophobicity, surface modification of ChNFs<sup>[8]</sup> or blending ChNFs with hydrophobic materials is a viable strategy<sup>[9]</sup>. However, these are not suitable for casting films from aqueous dispersions. Cheng et al.<sup>[10]</sup> demonstrated that the water resistance of ChNF films could be improved through deacidification and vacuum heat treatment. Deacidification eliminates the electrostatic repulsion introduced during ChNF preparation, and facilitates the formation of hydrogen bonds between nanofibrils. Meanwhile, vacuum heat treatment promotes the formation of hydrophobic covalent bonds, such as ester and amide bonds. The mechanisms of the films modified by the above two methods have been clarified. However, the properties and applications of these films have not yet been fully discussed.

Tannic acid (TA) is a naturally occurring water-soluble polyphenol that is frequently employed as a physical cross-linking agent for polymers<sup>[11-12]</sup>. This is due to the abundance of hydroxyl groups in its chemical structure. Double or triple hydrogen bonding can be formed by the gallic acid groups of TA, which is stronger than a single-ligand hydrogen bonding<sup>[13]</sup>. This multiple hydrogen bonding allows TA to form a dense hydrogen-bonding network within polymer materials. Additionally, TA is often studied for its antioxidant and antibacterial properties when incorporated into polymers<sup>[14-15]</sup>.

Herein, deacidification and vacuum heat treatment are employed as viable methods to enhance water resistance. TA is utilized as both a cross-linking agent and a functional additive. Consequently, the wet-state mechanical properties of the films, as well as functionalities, are further evaluated. Additionally, the

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\* Correspondence should be addressed to JI Yali, email: jiyali@dhu.edu.cn

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appropriate WVP and oxygen barrier. A packaging film with appropriate WVP is able to reduce system humidity and inhibit microbial growth<sup>[44]</sup>. However, CF-sealed strawberries show moldy, suggesting that WVP is not a major factor of freshness retention capacity. The superior preservation of strawberries by CTF may be attributed to TA's enhancement of the film's resistance to oxidation, UV shielding, and antibacterial properties as reported in Ref. [45]. Overall, CTF holds potential for strawberry preservation.



Fig. 9 Time-lapse photographs of strawberries sealed by different films

### 3 Conclusions

In this study, the structure, water resistance, mechanical properties and functionality of the deacidified ChNF films were further evaluated on the basis of previous studies. Deacidification would promote the coalescence of the nanofibrils, which facilitated the enhancement of the films' water resistance and mechanical properties. The ChNF films with TA had lower water absorption and higher wet-state mechanical properties, which was attributed to the physicochemical cross-linking between TA and chitin. TA also conferred excellent antioxidant and antibacterial properties on the films, making the films potentially useful for strawberry preservation. These findings would lay the foundation for the development of sustainable fruit packaging materials and demonstrate the broad prospects of chitin films in replacing traditional petroleum-based packaging materials.

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## 脱酸甲壳素纳米纤维膜的性能评估及其应用探索

柴恺彦, 吉亚丽\*, 孙 宾

东华大学 先进纤维材料全国重点实验室 材料科学与工程学院, 上海 201620

**摘要:** 为减少对石油资源的依赖, 多糖基材料的应用研究正成为主流趋势之一。甲壳素纳米纤维(chitin nanofibril, ChNF)在水相制备甲壳素薄膜方面展现出良好的应用前景。本研究在经过脱酸处理的ChNF薄膜中引入单宁酸(tannic acid, TA)作为交联剂和功能添加剂。随后, 评估了脱酸ChNF薄膜的结构和性能, 并探索了其在水果包装中的应用潜力。采用扫描电子显微镜对薄膜断面形貌进行了表征, 结果表明脱酸有助于薄膜的致密化, 从而改善耐水性。TA的添加进一步改善了薄膜的湿态力学性能、抗氧化能力、紫外屏蔽性和抗菌活性, 同时使薄膜保持了一定的透光性。引入TA的薄膜的拉伸强度达到 $(145.1 \pm 9.3)$  MPa, 其抗氧化活性超过95%。此外, 初步试验证实该薄膜在草莓保鲜方面具有潜力。

**关键词:** 甲壳素纳米纤维(ChNF); 单宁酸(TA); 脱酸; 浇铸; 水果包装