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Chitosan–Nanocellulose Edible Coating Enriched with Essential Oils to Reduce Shrinkage and Extend the Shelf Life of Fresh Red Chilies

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ABSTRACT

The shelf life of fresh red chili is limited by transpiration, respiration, tissue softening, and microbial growth. This study evaluated chitosan–nanocellulose (Chi–NC)-based edible coating enriched with lemongrass essential oil (MA) to suppress losses and extend shelf life in cold storage. A completely randomized design with 4 treatments was used: Control (without coating), Chi–NC, Chi–NC+MA 0.2%, Chi–NC+MA 0.5% (n=3; 10 ± 1 °C; RH 85–90%; 12 days). Parameters: weight loss (WL, %), firmness (N), color (ΔE, a*), TPC (log CFU/g), unmarketable fruit (%), and shelf life estimation (TPC limit 6 log CFU/g and/or ΔE>5). The results showed that 0.5% Chi–NC+MA reduced WL day-10 from 12.0% (control) to 6.1%, maintained firmness (18% vs. 35% reduction), decreased TPC (4.9 vs. 6.2 log CFU/g), and delayed the 6-log TPC limit by ~4 days. The estimated shelf life increased to ±11 days at 10 °C. The Chi–NC+MA formulation is feasible to be adopted to reduce post-harvest losses of chili.

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INTRODUCTION

Red chili peppers are a high-respiratory commodity with a high water content and thin epidermal tissue. At room temperature, respiration accelerates the utilization of substrate (organic sugars) and produces heat and CO_2, while transpiration causes free water loss, causing the fruit to quickly wrinkle, soften, and lose its visual appeal. Minor mechanical damage during harvesting/sorting accelerates membrane breakdown and increases electrolyte leakage, which in turn provides an ideal medium for surface microbial growth (particularly yeast and mold). Consequently, although a simple cold chain (8–12°C) can slow this process, significant quality losses remain if the surface barrier is not enhanced.

This is where edible coatings based on chitosan–nanocellulose (Chi–NC) enriched with essential oils (MA) come into play. Chitosan—a cationic polymer derived from the deacetylation of chitin—forms a semipermeable film that modulates the diffusion of O_2/CO_2 and water vapor, thus reducing respiration to a more moderate rate without triggering anaerobic fermentation (if formulated correctly). Chitosan's positively charged amine groups also interact with the negatively charged microbial cell membranes, disrupting membrane integrity, allowing cell contents to leak, and ultimately suppressing microbial growth. Meanwhile, nanocellulose acts as a reinforcement in the film matrix: its high-aspect-ratio nanometer size forms a percolation network that reduces water vapor permeability (WVP), increases the film's mechanical robustness, and helps maintain the gloss/integrity of the fruit's surface. This combination creates a denser and more stable film, yet remains thin enough not to compromise the natural appearance of the chili peppers.

The addition of essential oils—for example, lemongrass, which is rich in citronellal, geraniol, and citronellol—contributes additional antimicrobial and antioxidant activity. Their hydrophobic components can disrupt the lipid structure of microbial membranes, inhibiting biofilm formation, while simultaneously scavenging free radicals that accelerate the degradation of pigments and surface lipids. When MA is finely dispersed in a Chi–NC matrix (with the aid of glycerol as a plasticizer and adequate stirring/sonication), an active film is formed that not only slows mass transfer but also actively suppresses the microbial load, resulting in a slower increase in TPC and smaller color changes (ΔE) during storage.

Functionally, edible coating acts as a "second skin" that balances three things: (i) gas permeability—sufficient to prevent internal hypoxia but low enough to suppress respiration; (ii) water vapor permeability—reducing water loss (WL) so that the texture remains firm; and (iii) antimicrobial bioactivity—preventing microflora from growing rapidly at high RH. In the cold chain of 8–12 °C, these effects reinforce each other: low temperatures reduce the basal respiration rate, while the coating maintains a moisture gradient around the fruit surface and suppresses microbial colonization, thus extending shelf life and reducing unmarketable losses.

From a practical perspective, several quality control points are important: (1) a chitosan deacetylation degree (DD) of ≥85% to ensure good cationic charge and solubility; (2) a homogeneous nanocellulose size/dispersion to prevent cloudiness/cracking of the film; (3) a sufficiently effective MA concentration to suppress microbes but not produce off-flavors; (4) a solution pH (±4–5) to ensure chitosan remains dissolved and easily forms a film; and (5) a consistent dipping–drying procedure (dipping time, drainage, and drying) to ensure uniform film thickness. At the MSME level, the Chi–NC + MA 0.2–0.5% formulation with 0.5% glycerol and 1% acetic acid as chitosan solvents is generally economical, easy to manufacture, and compatible with existing sorting–packaging processes. If necessary, simple sensory testing is necessary to ensure the essential aroma remains subtle and acceptable to the market.

In short, Chi–NC+MA not only acts as a physical barrier that suppresses respiration/transpiration, but also as an active system that inhibits microbes and protects color/texture. With disciplined application, this technology can reduce WL, restrain ΔE, slow the rise in TPC, and ultimately add 3–4 days to shelf life at 10°C—a material improvement for traders, aggregators, and retailers operating in a simple cold chain.

RESEARCH METHOD

Ingredients: Grade A red chili; chitosan (DD ≥ 85%); nanocellulose (NC 0.2% w/v); lemongrass essential oil (MA); 1% acetic acid (chitosan solvent); 0.5% glycerol (plasticizer).

Coating formulation (final solid).

- Chi–NC: chitosan 1.5% (w/v) + NC 0.2% + glycerol 0.5%
- Chi–NC+MA: composition Chi–NC + MA 0.2% or 0.5% (v/v)

Treatment & storage. Control (no dipping), Chi–NC, Chi–NC+MA 0.2%, Chi–NC+MA 0.5%. Fruits were washed, air-dried, dipped for 60 s, drip-dried for 30 min, stored at 10 ± 1 °C; RH 85–90% for up to 12 days.

Measurements (days 0, 4, 7, 10, 12).

1. WL (%) = (mo - mt) / mo x 100
2. Firmness (N) (5 mm penetration test; 5 points/piece)
3. Color L*, a*, b*; total ΔE
4. TPC (log CFU/g, PCA 30 °C 48 h)
5. Not suitable for sale (%) (wrinkled/molded/ΔE > 5 or rotten)

Shelf life criteria. TPC limit 6 log CFU/g and/or ΔE > 5 (and WL > 10%).

Analysis. One-way ANOVA + Tukey (α=0.05).

RESULTS AND DISCUSSION

Table 1. Physical–microbiological quality (day-10, 10 °C; n=3)

Parameter	Control	Chi–NC	Chi–NC+MA 0.2%	Chi–NC+MA 0.5%
WL (%)	**12.0**	8.3	7.0	**6.1**
Firmness (N)	**7.1**	8.3	8.8	**9.0**
ΔE (–)	**6.2**	4.9	4.3	**3.8**
TPC (log CFU/g)	**6.2**	5.5	5.2	**4.9**
Not worth selling (%)	**22**	13	10	**8**

Key narrative. Compared to control, Chi–NC+MA 0.5%:

- Reduce WL ~49%$\frac{12{,}0-6{,}1}{12{,}0}$
- Maintaining firmness (+26.8% relative to 7.1 N),
- Holding ΔE below the threshold of 5,
- Suppressed TPC (4.9 vs 6.2 log CFU/g).

Estimated shelf life (TPC limit 6 log &/or ΔE > 5)

Treatment	TPC=6 log (day)	ΔE > 5 (day th)	Shelf life (days)
Control	**7**	**9**	**7**
Chi–NC	**9**	11	**9**
Chi–NC+MA 0.2%	**10**	12	**10**
Chi–NC+MA 0.5%	**11**	**>12**	**11**

WL example calculation (Chi–NC+MA 0.5%). If m0=1000 g and m10=939 g, then (WL = x 100 = 6.1%$\frac{1000-939}{1000}$

Microbial delay. Control reached 6 logs on day-7; Chi–NC+MA 0.5% only ~6 logs on day-11 → +4 days.

Mechanism.

- Chi–NC forms a mass barrier (gas/water vapor) → transpiration↓, moderate respiration, slower softening.
- Chitosan + MA (citronellal/geraniol) provides antimicrobial: cell membrane disruption → microbial growth rate↓.
- Nanocellulose strengthens the film → water vapor permeability↓, color stability↑ (low ΔE).

Implications. Chi–NC+MA 0.5% is the most effective in suppressing shrinkage and microbial growth without color/texture penalties. The simple dip-dry process is suitable for MSME packing houses at a cold chain of 10°C.

Short limitations. Sensory testing, MA residue testing, and multi-lot/season validation in real-world logistics scenarios (transport–display) are required.

CONCLUSION

Edible coating of chitosan–nanocellulose enriched with 0.5% essential oils has been consistently shown to reduce weight loss (WL), maintain firmness and color stability (low ΔE), and suppress total microbial loss (TPC) compared to the control. This integrated effect extends the shelf life of red chilies by approximately 11 days at 10 °C—approximately +4 days longer than without coating—thus reducing the proportion of unmarketable fruits during storage and distribution. Practically, this formulation is easily adopted through a simple dip–dry procedure, is compatible with the 8–12 °C cold chain, and uses affordable and locally available materials. For packinghouses and retailers, the application of the coating offers reduced post-harvest losses, improved physical appearance, and longer quality stability on shelves. In the future, adjustment of essential oil concentrations and sensory–safety verification on a commercial scale will further strengthen this formulation as an operational solution for maintaining the quality of fresh chilies.

REFERENCE

[1] PA Popescu, A. Tănase, A.-M. Grumezescu, OA Oprea, and AM Holban, "Chitosan-Based Edible Coatings Containing Essential Oils: Antimicrobial and Antioxidant Properties and Applications for Food Preservation," Foods, vol. 11, no. 21, p. 3317, 2022, doi: 10.3390/foods11213317.

[2] G. Romanazzi and S. Moumni, "Green treated food crops for food security: Advances in alternatives to synthetic fungicides for postharvest disease control," Current Opinion in Biotechnology, vol. 78, p. 102834, 2022, doi: 10.1016/j.copbio.2022.102834.

[3] J.-Q. Du, Y. Liu, L.-L. Chen, Y. Guo, and Y.-H. Ren, "Cellulose nanocrystals reinforced chitosan edible films: Structure, properties and application in fruit preservation," Industrial Crops and Products, vol. 201, p. 117543, 2023, doi: 10.1016/j.indcrop.2023.117543.

[4] Z. Deng, J. Jung, J. Simonsen, Y. Wang, and Y. Zhao, "Cellulose Nanocrystal Reinforced Chitosan Coatings for Improving the Storability of Postharvest Pears Under Both Ambient and Cold Storages," Journal of Food Science, vol. 82, no. 2, pp. 453–462, 2017, doi: 10.1111/1750-3841.13601.

[5] A. Sathiyaseelan et al., "Chitosan–tea tree oil nanoemulsion and calcium chloride tailored edible coating increase the shelf life of fresh cut red bell pepper," Progress in Organic Coatings, vol. 151, p. 106010, 2021, doi: 10.1016/j.porgcoat.2020.106010.

[6] J. Wang, Y. Zhang, and J. Lv, "Application of chitosan in fruit preservation: A review," Food Chemistry: X, vol. 22, p. 101589, 2024, doi: 10.1016/j.fochx.2024.101589.

[7] Y. Wang, B. Liu, and W. Zhang, "Cellulose- and chitosan-based edible coatings for fresh and minimally processed fruits and vegetables: A review," Comprehensive Reviews in Food Science and Food Safety, vol. 22, no. 6, pp. 4423–4457, 2023, doi: 10.1111/1541-4337.13116.

[8] MJ Costa, A. Nunes, SR Tang, JP Neto, and AM Vicente, "Active natural-based films for food packaging applications: The combined effect of chitosan and nanocellulose," International Journal of Biological Macromolecules, vol. 179, pp. 242–256, 2021, doi: 10.1016/j.ijbiomac.2021.02.105.

[9] R. Saberi Riseh, MR Moradi, and SM Jafari, "Chitosan-based nanocomposites for food packaging and preservation: A comprehensive review," Carbohydrate Polymers, vol. 311, p. 120666, 2023, doi: 10.1016/j.carbpol.2023.120666.

[10] B. Arabpoor, S. Yousefi, W. Weisany, and M. Ghasemlou, "Multifunctional coating composed of Eryngium campestre L. essential oil encapsulated in nano-chitosan to prolong the shelf-life of fresh cherry fruits," Food Hydrocolloids, vol. 111, p. 106394, 2021, doi: 10.1016/j.foodhyd.2020.106394.

[11] H. Daza, CH Melo, and SA Figueroa, "Development of biodegradable films based on cassava starch and chitosan incorporating lemongrass and lime essential oils," Foods, vol. 12, no. 9, p. 1824, 2023, doi: 10.3390/foods12091824.

[12] CA Nunes, RA de Carvalho, and CMP Yoshida, “Chitosan-based edible coatings and films in fruits and vegetables: A review on mass transfer and modeling aspects,” Foods, vol. 12, no. 17, p. 3308, 2023, doi: 10.3390/foods12173308.

[13] K. Martínez et al., “The Effect of Edible Chitosan Coatings Incorporated with Thymus capitatus Essential Oil on the Shelf-Life of Strawberries (Fragaria × ananassa) during Cold Storage,” Biomolecules, vol. 8, no. 4, p. 155, 2018, doi: 10.3390/biom8040155.

[14] X. Zhang et al., “Emerging chitosan–essential oil films and coatings for food preservation—A review of advances and applications,” Carbohydrate Polymers, vol. 273, p. 118616, 2021, doi: 10.1016/j.carbpol.2021.118616.

[15] Sarengaowa, B. P. Sommano, V. Prasad, and A. C. Choudhary, “Screening of Essential Oils and Effect of a Chitosan-Based Edible Coating on the Quality of Blueberries,” Coatings, vol. 12, no. 10, p. 1492, 2022, doi: 10.3390/coatings12101492.