International Food Research Journal 32(3): 712 - 723 (June 2025)
Journal homepage: *http://www.ifrj.upm.edu.my*

Fresh-keeping coating properties of corn whisker polysaccharide composite

[1]Li, S. T., [1]Yao, Q. M., [2]Yan, X., [2]Li, Y. J. and [2]*Hao, J. X.

[1]*Hebei Chemical and Pharmaceutical College, 050026 Shijiazhuang, China*
[2]*College of Food Science and Biology, Hebei University of Science and Technology, 050018 Shijiazhuang, China*

Article history

Received:
19 April 2024
Received in revised form:
16 May 2025
Accepted:
19 May 2025

Keywords

fresh-cut apple,
corn whisker polysaccharide,
coating agent,
fresh-keeping,
response surface tests

Abstract

The rapid oxidation of fresh-cut surface of apples, which is prone to browning, poses a challenge. Corn whisk polysaccharide, known for its antioxidant properties, is a promising candidate for the development of a novel fresh-keeping coating to enhance storage quality, and extend the shelf life of fruits and vegetables. In the present work, corn whisk polysaccharide was combined with nine types of thickening agents, antioxidants, and bacteriostatic agents to formulate the coating agent. Based on sensory score, colour difference, weight loss rate, and enzyme activity, the study assessed the fresh-keeping efficacy of various coating agents on fresh-cut apples stored for 5 d at 4°C. Response surface testing identified the optimal composite coating formulation as follows: corn whisk polysaccharide at 0.49%, sodium alginate at 0.53%, phytic acid at 1.23%, and lysozyme at 1.02%. These conditions resulted in a $\triangle L^*$ value of 0.938 for the fresh-cut apples. Further investigation into the antioxidant properties revealed that the activities of PPO (polyphenol oxidase) and POD (peroxidase) in the coated apples were lower compared to the blank control group during storage. This suggested that the composite preservative coating agent could enhance visual quality, and prolong the shelf life of fruits and vegetables.

DOI

https://doi.org/10.47836/ifrj.32.3.07

Introduction

In recent years, the increasing consumer demand for nutritional value and convenience has driven a rise in the market share of fresh-cut fruits and vegetables (Kostić *et al*., 2023). This changing market landscape has spurred continuous improvements in product quality within the fruit and vegetable industry (Pu *et al.*, 2023). However, the processing of certain fresh-cut fruits and vegetables like apples, pears, and lettuce involves mechanical cutting, which disrupts cell structures, leading to enzymatic browning of polyphenols upon exposure to oxygen catalysed by polyphenol oxidase (Chen *et al*., 2024a). Additionally, factors such as surface transpiration of fresh-cuts and bacterial contamination further contribute to a significant reduction in the shelf life of these produce items (Chang *et al*., 2023). The traditional preservation approach predominantly involves plastic packaging, which poses environmental pollution risks, and the potential ingestion of harmful substances like microplastics and plasticisers by humans (Guan *et al*., 2023). Therefore, the development of new green preservation coatings is very important for the preservation and storage of fruits and vegetables, thus promoting food safety, and advancing the food industry (Chavan *et al*., 2023).

Corn whisk polysaccharide, a key functional component of corn whiskers (Sawangwong *et al*., 2024), primarily comprises glucose, xylose, galactan, pentosan, and hexose (Liu *et al*., 2024). This polysaccharide, a representative compound in both medicine and food, exhibits anti-tumour, hypoglycaemic, immune-modulating, and antioxidant properties (Li *et al*., 2021; Zhu *et al.*, 2024). Studies have highlighted the ability of dietary antioxidants to mitigate gut inflammation and mucosal damage by scavenging reactive oxygen species, suppressing inflammatory pathways, and bolstering antioxidant defences (Jia *et al*., 2021). A previous study demonstrated that corn silk polysaccharide (CSP2) could suppress oxidant stress by improving the enzyme activities of superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPX) (Guo *et al*., 2019). At present, corn whisk polysaccharide is mostly employed in clinical investigations and medical interventions, with limited

*Corresponding author.
Email: 349904844@qq.com

exploration into its edible applications. Leveraging its potential value, particularly its antioxidant properties, in the food industry for the development of a novel edible coating agent could present substantial market opportunities.

In the present work, a novel edible fresh-keeping coating was developed by studying the content and proportion of corn whisker polysaccharide, thickening agent, antibacterial agent, antioxidant, and other active ingredients. The present work aimed to analyse the colour and texture variations of fresh-cut apples over storage duration to enhance shelf life and preserve nutritional content.

Materials and methods

Reagents

The present work used ripe apple (*Malus pumila* Mill); corn whisker polysaccharide (extracted at 90°C with hot water and precipitated with ethanol); food additives (gelatine, sodium alginate, water-soluble chitosan, tea polyphenols, lactostreptococcin (nisin), lysozyme, and phytic acid) from Xintai Biotechnology Co., Ltd.; onion extract (30:1) from Xi'an Youshuo Biotechnology Co., Ltd.; food-grade cinnamon essential oil from Jiangxi Yuan Shangxiang Herb Co., Ltd.; and food-grade glycerine from Wilmar Oil Technology (Shanghai) Co., Ltd.

Handling of apples

Apples at optimal ripeness, exhibiting freshness, uniformity in size, and absence of physical imperfections, were chosen and stored at 4°C. Following 24-h storage, the apples underwent washing with running water, peeling, coring, and segmentation into eight uniform parts. A group of ten apples was randomly selected for further analysis.

Single factor test

Solutions of corn whisk polysaccharide at mass fractions of 0.10, 0.30, 0.50, 0.70, and 0.90% were prepared. Fresh-cut apple samples were soaked in the prepared solution for 2 min, air-dried at room temperature, placed in plastic containers, covered with plastic wrap, and stored at 4°C. Sensory evaluations, weight loss measurements, hardness assessments, and colour difference analyses were conducted on days 0, 1, 3, and 5. Uncoated samples served as blank controls, and the weight loss rate was determined using gravimetric analysis. Hardness was determined by puncture method with texture apparatus (Stable Micro System, UK) (Adainoo *et al*., 2023). Colour difference L* was measured with automatic colour difference meter (Minolta CR-400, Konica Minolta Holdings, Inc. Japan), with measurements taken at three different locations on each sample, and the average value recorded (Zuo *et al*., 2021).

Solutions of sodium alginate at concentrations of 0.5, 1.0, 1.5, 2.0, and 2.5%, gelatine at concentrations of 4.0, 5.0, 6.0, 7.0, and 8.0%, and chitosan at concentrations of 1.25, 1.50, 1.75, 2.00, and 2.25% were prepared. All solutions were plasticised with 1.0% glycerol, thoroughly mixed at room temperature, and degassed using ultrasound (KS-800 KDE high power liquid crystal ultrasonic cleaner; Baoji Xinyu Optoelectronic Co., LTD.). Fresh-cut apple samples were soaked in the prepared solution for 2 min, air-dried at room temperature, placed in plastic containers, covered with plastic wrap, and stored at 4°C. The weight loss rate was utilised as the evaluation criterion.

Solutions of tea polyphenol at concentrations of 0.25, 0.50, 1.00, 1.50, and 2.00%, onion extract at concentrations of 2.0, 4.0, 6.0, 8.0, and 10.0%, and phytic acid at concentrations of 0.50, 0.75, 1.00, 1.25, and 1.50% were prepared. These solutions were thoroughly mixed at room temperature, and degassed using ultrasound. Fresh-cut apple samples were soaked in the prepared solution for 2 min, air-dried at room temperature, placed in plastic containers, covered with plastic wrap, and stored at 4°C. Colour difference was utilised as the evaluation parameter.

Solutions of nisin at concentrations of 0.01, 0.03, 0.05, 0.07, and 0.10%, cinnamon essential oil at volumes of 3, 4, 5, 6, and 7 μL/mL, and lysozyme at concentrations of 0.5, 1.0, 1.5, 2.0 and 2.5% were prepared. The diameter of the bacteriostatic zone against Enteropathogenic *E. coli* (G-) and *Staphylococcus aureus* (G+) was measured to evaluate the bacteriostatic efficacy.

Sensory experiment

Twenty people were selected to score the samples using the ten-point system (3 points for colour, 2 points for texture, 2 points for smell, and 3 points for taste). Samples scoring between 8 and 10 were categorised as fresh fruit, those scoring between 6 and 8 were classified as secondary fruit, and samples scoring less than 6 were designated as non-fresh fruit (Kim *et al*., 2023). Polyphenol oxidase (PPO) activity was assessed using the catechol method (Huang and He, 2023), peroxidase activity (POD) was determined by guaiacol method (Asghari and Hasanlooe, 2015), bacteriostatic effect was determined by polypeptide bacteriostatic zone method, and total number of bacterial colonies was determined following the protocol by Stevens *et al.* (2018).

Response surface test

The alteration in colour difference L* serves as a prominent indicator of fruit and vegetable browning, commonly employed to assess preservation effectiveness. Design-Expert 13 software was used to establish a 4-factor and 3-level model scheme (established on single factor experiment result: corn whisk polysaccharide, 0.5%; sodium alginate, 0.5%; phytic acid, 1.25%; and lysozyme, 1.0%), aiming to optimise the composite coating agent formulation based on the colour difference change △L* following 5-d storage.

Statistical analysis

Statistical analysis was conducted using SPSS 22.0 software. The mean values were statistically evaluated *via* One-way ANOVA ($p < 0.05$).

Results and discussion

Effect of different concentrations of corn whisker polysaccharide on fresh-cut apples

Sensory evaluation serves as a direct measure to evaluate the quality of fresh-cut fruits and vegetables (Ali *et al.*, 2024). In Figure 1A, the sensory score of the control group exhibited a notable decrease within the initial 3-d storage. By day 5 of storage, the sensory score of the apple samples reached 4.8 ± 0.3 points, displaying signs of wrinkling, water loss, softening in texture, pronounced browning, and a loss of marketable characteristics. The sensory score of apple samples coated with corn whisker polysaccharide was significantly higher than that of the blank group. During the initial 3-d storage, the score increased by 25.4 to 34.3% compared with that of the blank group. On day 5 of storage, the sensory scores remained above 7 points, indicating a classification within the sub-fresh category. With a 0.5% coating solution, the apple samples achieved sensory scores of 8.1 ± 0.2 points, exhibiting light yellow coloration, relatively moist surfaces, brittle but not overly firm textures, and remained suitable for commercial sale. This outcome can be attributed to the low oxygen permeability of the coating, which hindered oxygen exposure to the apples, thus preserving moisture content and surface colour (Vargas-Torrico *et al.*, 2023). Moreover, the inherent antioxidant properties of corn whisk polysaccharide contributed significantly to prolonging the shelf life of fresh-cut apples.

The weight loss rate of fresh-cut apples during storage significantly increases due to the rapid dissipation of water from the fresh-cut surfaces. As depicted in Figure 1B, the weight loss rate of the uncoated group increased sharply within 2 d, reaching 6.27 ± 0.015% on day 5 of storage. Conversely, following coating application, the weight loss rate exhibited a slower increase, with the coated group showing a decrease in weight loss rate by 35.72 - 81.02% compared with that of the blank group on day 5 of storage. This indicated that the coating treatment effectively suppressed transpiration. The polysaccharide solution, containing various monosaccharides and low-molecular-weight polysaccharides, exhibited hygroscopic properties, and the dense coating film enhanced water retention effects (He *et al.*, 2012). Additionally, the weight loss rate showed a negative correlation with hardness (Figure 1C), consistent with findings by Wu *et al.* (2023).

The L* value serves as a crucial parameter indicating the surface brightness of fresh-cut apples, with higher values corresponding to greater brightness (Ghidelli *et al.*, 2015). Over time, the L* value of fresh-cut apples showed a rapid decrease due to cell structure damage post-cutting, leading to reactions between phenols and enzymes like PPO, inducing enzymatic browning and consequent decrease in the L* value (Franck *et al.*, 2007). Therefore, calculating △L* before and after storage provides insight into the degree of browning. In Figure 1D, the L* value exhibited the most significant change in the blank group on day 5 of storage, while minimal variation was observed after coating. With an increase in polysaccharide concentration, the △L* value demonstrated an initial decrease followed by an increase, reaching the minimum at 0.5%. This suggested that the antioxidant capacity improved with increasing polysaccharide concentration. However, higher polysaccharide concentrations may increase impurity levels in the crude polysaccharide solution, deepening the colour of the coating solution, thereby influencing the L* value.

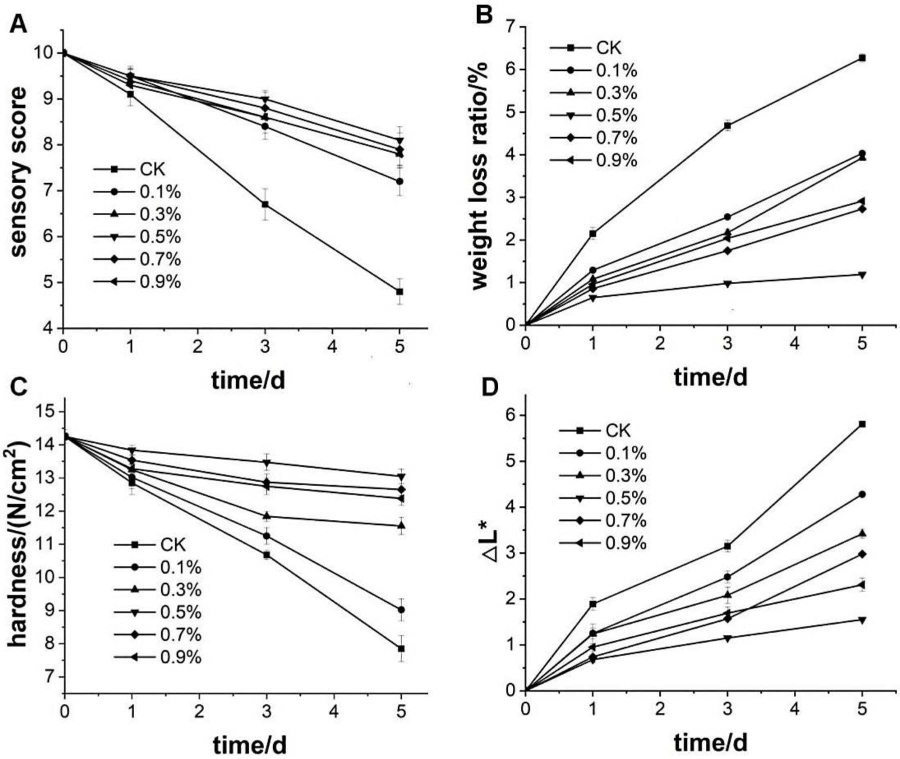

Figure 1. Fresh-keeping properties of fresh-cut apples treated with different concentrations of corn whisker polysaccharide during five days of storage. **(A)** Sensory score; **(B)** weight loss ratio; **(C)** hardness; and **(D)** colour difference.

Effects of different thickeners on fresh-cut apples

In Figure 2A, the weight loss rate of fresh-cut apples treated with different thickeners on day 5 of storage is depicted. The results clearly indicated that the water retention efficacy of the sodium alginate group on fresh-cut apples surpassed that of the gelatine and chitosan groups. The weight loss of apple samples treated with different concentrations of sodium alginate ranged from 0.89 to 2.84%, with an average weight loss that was 37.16 and 66.45% lower than that of the gelatine and chitosan groups, respectively. This superiority can be attributed to the strong hydrophilicity and high viscosity of sodium alginate. In comparison to other alternatives, sodium alginate demonstrated enhanced softness, uniformity, and a robust protective effect (Yan *et al*., 2023). However, to improve the transparency and gel strength of the coating solution, acetic acid was incorporated during the preparation process, albeit resulting in decreased water retention. Among the 16 experimental groups, the treatment with 0.5% sodium alginate yielded the lowest weight loss rate, with an increase in weight loss rate corresponding to higher sodium alginate concentrations. This indicated that the sodium alginate solution concentration should be optimised within an appropriate range to ensure optimal viscosity and semi-permeability of the coating. Excessive thickness of the coating due to a highly concentrated sodium alginate solution can impede substance exchange between the fresh-cut apple and its surroundings, potentially compromising the apple's inherent regulatory capacity (Deng *et al*., 2024).

Effect of different antioxidants on fresh-cut apple

The overall antioxidant activity of phytic acid group exceeded that of the tea polyphenol and onion extract groups, as evidenced by the lower △L* value (Figure 2B). In the blank group, L* value decreased from 79.35 to 71.54 after 5-d storage, while with the 1.25% phytic acid coating, the L* value decreased only slightly from 79.35 to 78.08 under the same conditions, maintaining a bright colour. Phytic acid, a natural compound with robust antioxidant capabilities, is notably characterised by its potent metal ion chelation properties. The strong chelation of phytic acid to metal ions can reduce the oxidation rate of polyphenol oxidase to phenolic compounds, presenting significant benefits for preserving apples susceptible to browning (Gong *et al*., 2023; Chen *et al*., 2024b).

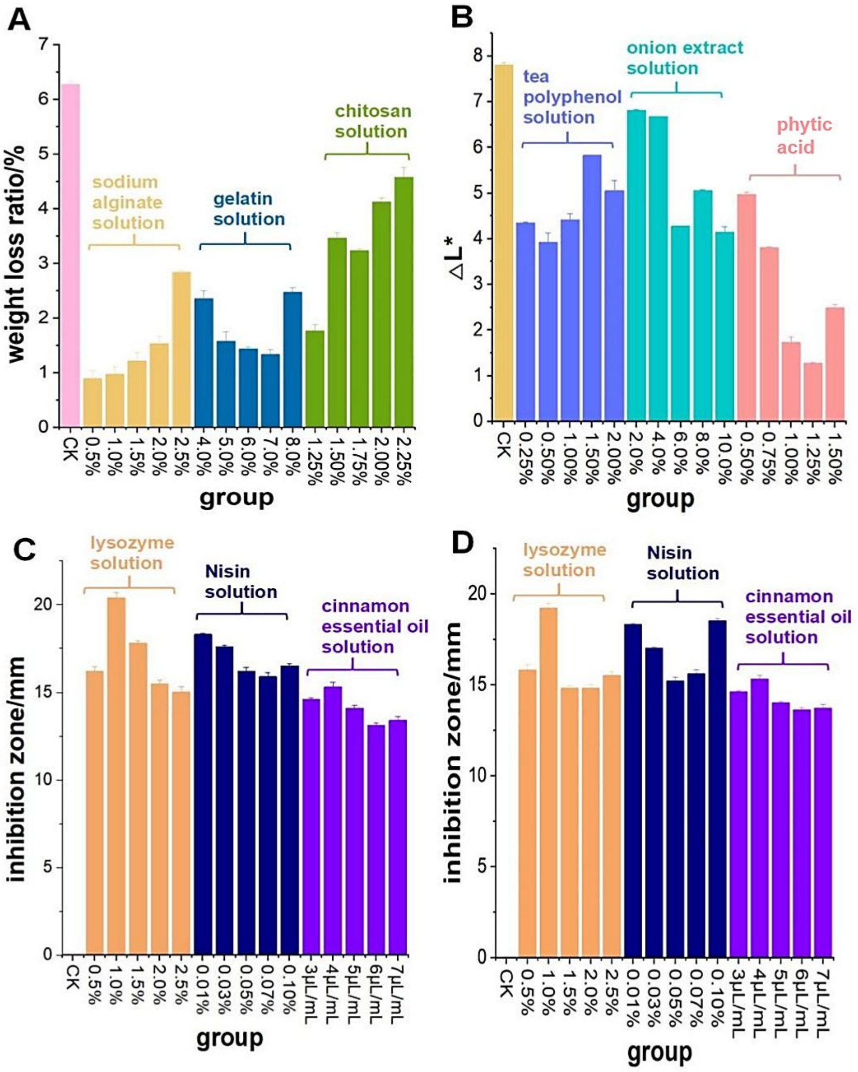

Figure 2. Fresh-keeping properties of fresh-cut apples after coating with different additives. **(A)** Weight loss rate of fresh-cut apples treated with different thickeners on day 5 of storage; **(B)** colour difference △L* value of fresh-cut apples treated with different antioxidants on day 5 of storage; the size of inhibitory circles for **(C)** *Staphylococcus aureus* (G+) and **(D)** *Escherichia coli* (G-) after treatment with different antibacterial agents.

Bacteriostatic effect of different bacteriostatic agents

Figures 2C and 2D illustrate the zone of inhibition values for *S. aureus* and *E. coli* cultured on plate medium for 48 h with different antibacterial agents. Overall, the bacteriostatic effect of lysozyme group and *Lactostreptococcus* group was similar, with bacteriostatic zone sizes ranging around 14 - 20 mm. The cinnamon essential oil group demonstrated the least effective outcome, with antibacterial zone sizes approximately 13 - 16 mm, potentially attributed to essential oil evaporation due to the filter paper method, resulting in lowered essential oil concentrations.

Due to the varying thickness and structure of the peptidoglycan layer in the cell walls of Gram-positive and Gram-negative bacteria, the antibacterial effect of antibacterial agents differed between the two types of bacteria (Luo *et al*., 2022). For *S. aureus* (G+), the average inhibitory zone size was 17.0 mm in the lysozyme group, and 16.9 mm in the *Lactostreptococcus* group, both demonstrating effective inhibitory performance. This effectiveness can be attributed to lactostreptococcin, a cationic peptide that interacts hydrophobically or electrostatically with anionic components (such as teichoic acid, lipid teichoic acid, acidic polysaccharide, and phospholipid) in the peptidoglycan layer of bacterial cell wall. This interaction disrupts the cell membrane, leading to cytoplasmic leakage and bacterial cell death

(Bermudez-Aguirre and Niemira, 2023). At a concentration of 0.01% lactostreptococcin solution, the antibacterial zone diameter peaked at 18.3 ± 0.071 mm. Lysozyme primarily exerts its bacteriostatic effect through peptidoglycan degradation in the bacterial cell wall, exhibiting effective action against Gram-positive bacteria (Shao *et al*., 2024). Enhanced efficacy was observed with the addition of 1% lysozyme, resulting in a bacteriostatic zone diameter of up to 20.4 ± 0.283 mm. In the case of Gram-negative bacteria, which have thinner and more complex cell walls compared to Gram-positive bacteria, the inhibitory effect of *Lactostreptococcus* and lysozyme on *E. coli* (G-) was slightly worse. The average inhibitory zone diameter for both groups was 16.1 mm. Comparing the maximum inhibitory zone diameters in the two groups, the lysozyme group demonstrated superior inhibitory efficacy. With the addition of 1% lysozyme, the largest inhibitory zone diameter was observed, measuring 19.2 ± 0.141 mm. Relevant studies have shown that lysozyme exhibited notable dissolution effects on Gram-negative bacteria like *E. coli* and *Vibrio parahaemolyticus* (Zhang *et al*., 2024). Considering the combined inhibitory effects of the three bacteriostatic agent groups against *S. aureus* (G+) and *E. coli* (G-), lysozyme's bacteriostatic action is broad-spectrum and highly efficient, with optimal efficacy achieved at a 1% dosage.

Response surface test results

Based on the single-factor test results detailed earlier, response surface optimisation trials were conducted utilising a design comprising four factors and three levels. The data were scrutinised, and a quadratic regression model for the △L* value in relation to the incorporation of corn whisker polysaccharide (A), phytic acid (B), sodium alginate (C), and lysozyme (D) was obtained as follows:

$$Y = 1.01 - 0.29 \times A - 0.77 \times B + 0.33 \times C + 0.43 \times D - 0.44 \times AB + 0.26 \times AC + 0.29 \times AD - 0.83 \times BC + 0.42 \times BD + 0.62 \times CD - 1.20 \times A^2 - 3.80 \times B^2 - 1.35 \times C^2 - 2.69 \times D^2$$

To further verify the reliability of the model, a variance analysis was performed on the regression equation, and the results are presented in Table 1.

Table 1. Analysis of variance of regression equation.

	Sum of square	Degree of freedom	Mean square	F	P	Significance
Model	138.49	14	9.89	134.30	< 0.0001	**
A - Corn whisker polysaccharide	1.03	1	1.03	14.03	0.0022	**
B - Phytic acid	7.11	1	7.11	96.64	< 0.0001	**
C - Sodium alginate	1.29	1	1.29	17.57	0.0009	**
D - Lysozyme	2.17	1	2.17	29.44	< 0.0001	**
AB	0.78	1	0.78	10.64	0.0057	**
AC	0.27	1	0.27	3.60	0.0785	
AD	0.32	1	0.32	4.41	0.0543	
BC	2.76	1	2.76	37.43	< 0.0001	**
BD	0.70	1	0.70	9.47	0.0082	**
CD	1.55	1	1.55	21.05	0.0004	**
A^2	9.27	1	9.27	125.93	< 0.0001	**
B^2	93.69	1	93.69	1272.64	< 0.0001	**
C^2	11.83	1	11.83	160.70	< 0.0001	**
D^2	46.78	1	46.78	635.44	< 0.0001	**
Residual error	1.03	14	0.07			
Misfit error	0.54	10	0.05	0.44	0.87	non-significant
Pure error	0.49	4	0.12	21.05		
Sum total	139.52	28				
$R^2 = 0.99$; $R_{adj}^2 = 0.99$						

*$p < 0.05$, significant; **$p < 0.01$, extremely significant; $p > 0.05$, non-significant.

In the model, F = 134.37 and $p < 0.0001$, signifying the statistical significance of the regression model. The missing item $p = 0.87$, exceeding 0.05, indicated the insignificance of the missing item. With $R^2 = 0.99$ and $R_{adj}^2 = 0.99$, the model exhibited a strong fit, capable of capturing the response surface variations, and effectively describing the experimental outcomes. Consequently, it was deemed suitable for predicting the △L* value of fresh-cut apples. Within the experimental design's factor level scope, all four factors exhibited significant impacts on △L* values ($p < 0.01$). Based on the F-value, the effect sequence of four factors on △L* value of fresh-cut apples was phytic acid (B) > Lysozyme (D) > Corn whisker polysaccharide (A) > Sodium alginate (C). In addition, interactions AC and AD had no significant influence on △L* values ($p > 0.05$). Conversely, AB, BC, BD, and CD significantly affected the △L* value ($p < 0.01$). In the quadratic terms, A^2, B^2, C^2, and D^2 exhibited significant effects on browning degree ($p < 0.01$).

The influence of two factors on the value of △L* was then investigated. The response surface and contour diagram could directly reflect the influence of each parameter on the response value, as depicted in Figure 3. The response surfaces for AB, BC, BD, and CD exhibited steepness, and the contour map appeared more elliptical and dense at higher values, indicating a stronger influence of the interactions of AB, BC, BD, and CD on the △L* value. Conversely, the response surfaces and contour lines for AC and AD were smoother, indicating non-significant interactions, aligning with the ANOVA results. Response surface software was employed to optimise the dosage of the composite coating agent, resulting in the following optimal formulation: corn whisker polysaccharide, 0.49%; phytic acid, 1.23%; sodium alginate, 0.53%; and lysozyme, 1.20%. Under these optimised conditions, the △L* value was measured at 0.915.

To validate the prediction accuracy of the response surface model, three sets of parallel experiments were conducted under optimal conditions, yielding a △L* value of 0.938 for fresh-cut apples. The difference from the experimental group may be caused by an error, with an error range of 2.5%, indicating the reliability of the model.

Effect of optimum composite coating agent on enzyme activity in fresh-cut apple

The optimum coating agent was applied to fresh-cut apples, and its impact on the enzyme activities of PPO and POD during storage was investigated. Additionally, variations in the total bacterial colony count in the samples were examined to assess the preservation properties of the composite coating agent in comparison to untreated fresh-cut apples.

PPO is a ubiquitous plant enzyme that exhibits increased activity in response to plant tissue damage or disease, contributing to stress resilience and self-protection within the organism (Li *et al*., 2023). Meanwhile, PPO serves as a crucial enzyme in the enzymatic browning process in plants (Cui *et al*., 2023).

In Figure 4A, PPO enzyme activity of fresh-cut apples exhibited a pattern of initial increase followed by a decrease during storage. On day 3 of storage, the highest PPO enzyme activity in the blank group was 0.68 ± 0.68 $\triangle OD_{398}$/min·g, surpassing that of the coated group by a factor of 1.51. With extended storage, the accumulation of enzymatic reaction products would inhibit PPO activity to a certain extent, leading to a subsequent decline in PPO enzyme activity on day 3 of storage. On day 5 of storage, the coated group displayed a PPO activity level merely at 33.75% of that in the untreated group, underscoring a significant inhibition of PPO activity in fresh-cut apples post-coating. These findings indicated that the composite coating agent could inhibit PPO activity in fresh-cut apple, thereby retarding the browning process it initiates.

POD serves as a pivotal enzyme in plants' oxygen radical scavenging system, facilitating the oxidation of phenolic compounds. Typically, POD levels are higher in aging tissues, commonly used as a marker for fruit senescence (Shen *et al*., 2023). In Figure 4B, the POD activity in fresh-cut apples displayed an initial increase followed by a decrease during storage, peaking on day 3 of storage. This pattern is attributed to the mechanical injury-induced damage to the fruit membrane system, accelerating cell wall degradation, increasing free POD content, and promoting enzymatic browning of apples (Jesus *et al*., 2018). Post-coating application, the POD enzyme activity was lower than that in blank group. On day 5 of storage, POD activity in the blank group was 56.40 ± 0.44 $\triangle OD_{460}$/min·g, representing only 62.41% of the coated group. This decrease may be attributed to the potent free radical scavenging

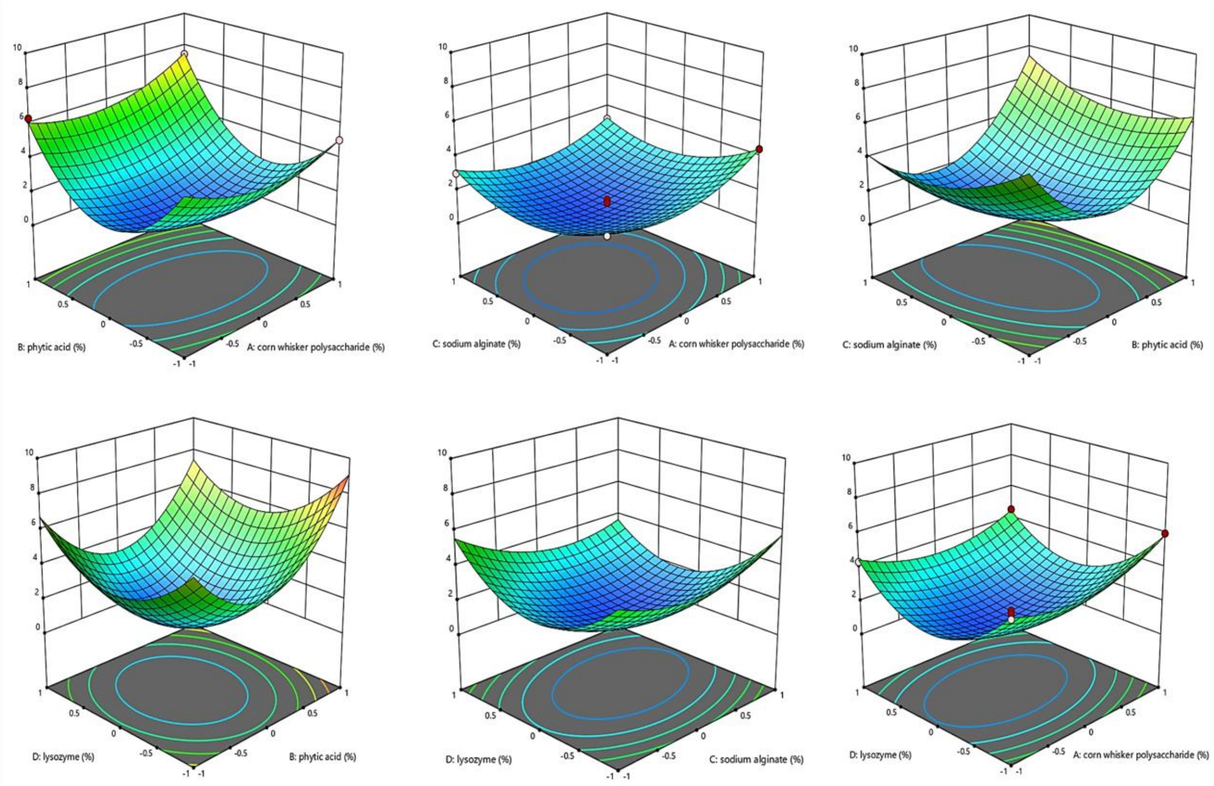

Figure 3. Response surface diagram of interaction of various factors to △L* value. **(A)** Corn whisker polysaccharide and phytic acid; **(B)** corn whisker polysaccharide and sodium alginate; **(C)** phytic acid and sodium alginate; **(D)** phytic acid and lysozyme; **(E)** sodium alginate and lysozyme; and **(F)** corn whisker polysaccharide and lysozyme.

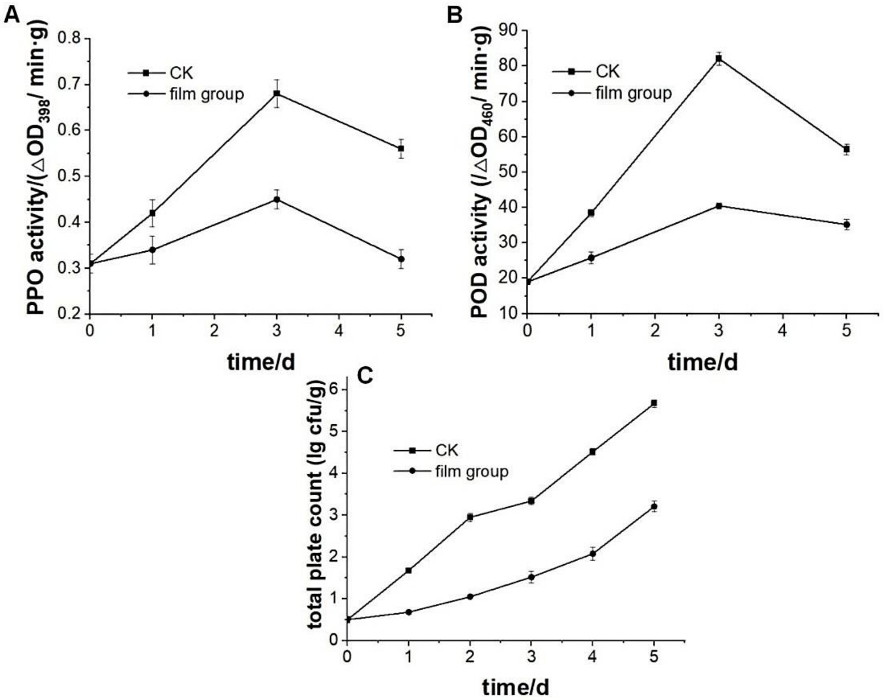

Figure 4. Fresh-keeping performance of fresh-cut apples treated with corn whisker polysaccharide composite fresh-keeping coating during five days of storage. **(A)** PPO activities; **(B)** POD activities; and **(C)** total bacterial colony counts.

capability of the composite coating agent, resulting in small changes in POD activity, slow down the aging rate, and delay the browning of fresh-cut fruits.

The total number of bacterial colonies is a crucial metric for assessing the level of microbial contamination in food products (Janecko *et al*., 2022). Over time, the total bacterial colony count in fresh-cut apples gradually increased. As depicted in Figure 4C, at equivalent storage durations, the total bacterial colony count in the coated group was notably lower than that in the untreated group. A significant ($p <$ 0.05) difference between the two groups was observed on day 1 of storage, with the disparity in bacterial colony count between the coated and untreated groups progressively widening after day 4 of storage. This decrease can be attributed to the antibacterial properties of corn whisk polysaccharide and lysozyme present in the composite coating agent, effectively inhibiting microbial growth.

Conclusion

In the present work, a novel coating material based on corn whisker polysaccharide was developed, specifically tailored for fresh-cut apple. Through single-factor and response surface testing, the optimised formulation was determined as follows: corn whisk polysaccharide, 0.49%; sodium alginate, 0.53%; phytic acid, 1.23%; and lysozyme, 1.20%. Subsequent verification tests demonstrated the effectiveness of this approach in inhibiting enzymatic browning of fresh-cut apples, significantly enhancing sensory quality, particularly evident after five days of storage. Moreover, the enzyme activity experiments demonstrated the favourable antioxidant effects of this method. Evaluation of the total colony count pre- and post-coating revealed enhanced antibacterial efficacy of the coating agent. These findings would provide valuable technical support and a foundation for the storage and preservation of fruits and vegetables, such as fresh-cut apples.

Acknowledgement

The present work was financially supported by the University Science and Technology Research Project of Hebei Province (grant no.: ZC2022037).

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