Valorization of Longan Seed Study on the Improvement of Parchment Using Dialdehyde Carboxymethyl Cellulose–Gelatin–Chitosan Composite Films Synthesis and Characterisation of Multifunctional Polymers for

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Study on the Improvement of Parchment Using Dialdehyde Carboxymethyl

Cellulose–Gelatin–Chitosan Composite Films

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Abstract:

This study investigates the improvement of parchment's physical properties using a dialdehyde carboxymethyl cellulose-gelatin-chitosan composite solution as a packaging material. The results indicate that the aldehyde groups in dialdehyde carboxymethyl cellulose form Schiff base linkages with the amino groups of chitosan, and establish covalent cross-linking with amino groups in parchment collagen fibers, thereby enhancing the structural integrity of the parchment. By impregnation treatment, the modified parchment exhibited a smoother surface, an increase in tensile strength to 16.60 kN/m, and a reduction in water vapor permeability to 0.059 mg/(cm²·h), indicating substantial improvements in mechanical strength barrier performance. This work provides a feasible modification method and a theoretical basis for expanding the application of parchment in the packaging field.

Keywords: Parchment; Dialdehyde carboxymethylcellulose; Mechanical strength; Barrier performance; Packaging field

1. Introduction

Compared to traditional paper-based materials, parchment paper made from animal skin shares similar renewable, biodegradable, and eco-friendly characteristics, while exhibiting significantly superior mechanical strength[1-2].

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However, its network structure, composed mainly of collagen fibers, contains pores that result in high water vapor permeability, limiting its suitability as a packaging material unless its barrier properties are improved. Modification using bio-based materials presents a viable approach to enhance its barrier performance while maintaining environmental friendliness.Dialdehyde carboxymethyl cellulose (DCMC), derived from the periodate oxidation of carboxymethyl cellulose, contains abundant aldehyde groups along its molecular chain [3]. Gelatin offers excellent film-forming and gelling properties [4], while chitosan is rich in amino groups that provide numerous crosslinking sites and contribute additional mechanical strength to composite materials

[5]. By combining DCMC, gelatin, and chitosan into a composite system, physical encapsulation and covalent crosslinking can effectively enhance the physical properties, barrier performance, and environmental reliability of parchment paper.

Parchment has garnered renewed interest in the field of sustainable materials in recent years due to its favorable biodegradability and low environmental footprint [6]. This study focuses on the application potential of parchment as a packaging material by modifying it through impregnation with a dialdehyde carboxymethyl cellulosegelatin-chitosan based solution, aiming to enhance its physical properties, barrier performance, and environmental reliability. The research seeks to expand the application scope of parchment in the packaging sector through material innovation.

2. Experimental section

2.1. Materials

Carboxymethyl cellulose (analytical grade) was supplied by Shanghai Aladdin Biochemical Technology Co., Ltd. Gelatin (chemical grade), sodium periodate (analytical grade), chitosan (biochemical reagent), and sodium thiosulfate pentahydrate (analytical grade) were all obtained from Sinopharm Chemical Reagent Co., Ltd. Glycerol, ethylene glycol, and anhydrous ethanol (all of analytical grade) were provided by Tianjin Fu Yu Fine Chemical Co., Ltd. Sulfuric acid (analytical grade) was sourced from Yantai Far East Fine Chemical Co., Ltd. Castor oil (analytical grade) was supplied by Tianjin Damao Chemical Reagent Factory. Potassium iodide (analytical grade) was purchased from Shanghai Yindian Chemical Co., Ltd. Soluble starch (analytical grade) was obtained from Xilong Scientific Co., Ltd. p-Anisidine (reagent grade) was provided by Shandong Keyuan Biochemical Co., Ltd.

2.2 Preparation of DCMC-Gelatin-Chitosan Composite Films

A 5 wt% carboxymethyl cellulose solution was mixed with a 10 wt% sodium periodate solution at a mass ratio of 2:1. The reaction was carried out at 30°C and pH 3 under light-proof conditions for 4 hours. Upon completion, ethylene glycol was added to quench the unreacted sodium periodate. The product was then precipitated as white flocs by adding excess anhydrous ethanol, followed by centrifugation at 8000 r/min for 5 minutes. The collected product was dialyzed using a dialysis membrane with a molecular weight cut-off of 8000–14000 Da, and finally freeze-dried to obtain DCMC, which was stored in a sealed container[7].

Solutions of 10 wt% gelatin, 1 wt% DCMC, and 1 wt% chitosan were prepared. The gelatin solution was first mixed with the DCMC solution at specified mass ratios and stirred at 60°C for 1 hour. The resulting mixture was

then blended with the chitosan solution at designated mass ratios. The specific mass ratios of DCMC to gelatin to chitosan used was 1:10:1. Glycerol was added at 3 wt% relative to the total solution mass, and the reaction continued at 60°C for an additional hour to form the filmforming solution. The solution was cast into polytetrafluoroethylene Petri dishes with a diameter of 9 cm and dried under vacuum at 40°C for 48 hours.

2.3 Preparation of Parchment

Parchment was produced from goat skins (from Lubai White goats) through a series of processes including soaking, liming, reliming, fleshing, deliming, degreasing, bating, and drying. The washed goat skins were treated in a 15% glycerol solution at 500C for 6 hours. The resulting parchment was then immersed in the base solution for modification, while the control group was immersed in water. After 1 hour of immersion, the samples were flattened using a flat vulcanizing machine under a pressure of 10 MPa and dried under vacuum at 400C for 48 hours.

2.4 Microstructural Morphology and Characterization

The microstructure of the samples was observed using a scanning electron microscope (Regulus 8220, Hitachi, Japan) with an acceleration voltage of 15 kV. The chemical structural characteristics were analyzed by a Fourier transform infrared spectrometer (ALPHA, Bruker, Germany) with a scanning range of 500–4000 cm-1. The carbon, hydrogen, oxygen, and nitrogen contents were determined using an elemental analyzer (Elementar Unicube, Elementar, Germany). The functional groups of the samples were characterized by X-ray photoelectron spectroscopy (ESCALAB Xi+, Thermo Fisher Scientific, USA).

2.5 Physical and Barrier Property Testing

In accordance with GB/T 1040.3-2006, the tensile strength and elongation at break of the samples were measured using an AI-3000 electronic tensile testing machine. With

reference to GB/T 455.1-2021, the tear index was determined by an Elmendorf-type tearing tester. In accordance with QB/T 2799-2006, the air permeability of the samples was determined using a leather air permeability tester (Gaotie Testing Instruments Co., Ltd.). With reference to GB/T 39369-2020, the water vapor permeability was measured by a water vapor transmission rate tester. Based on GB/T 461.3-2005, the water absorption rate was determined through experimentally designed procedures and calculations.

2.6 Environmental Reliability Testing

Samples were collected using a 10 cm × 10 cm standard mold, treated in an aging chamber at 35°C for 48 hours

[1], and rated by comparison with the ISO standard gray scale. The salt was equally divided into three groups, packaged, and stored under constant temperature and humidity for 10 days to monitor mass changes. The samples were cut and immersed in a simulated solution at 40°C for 5 days, then the filtered solution was analyzed by ICP-MS (Thermo Scientific iCAP RQ) [8]. Equal amounts of castor oil were sealed in each packaging

group and heated at 60°C for 7 days. Peroxide and anisidine values were measured per ISO 6885:2016, and total oxidation value was calculated.

3. Results and Discussion.

3.1 Structural Characterization Analysis

As shown in Figure 1, scanning electron microscopy (SEM) images comparing the morphology of parchment before and after impregnation modification reveal a noticeably smoother surface in the modified sample. The untreated parchment surface exhibits micron-scale pores and uneven structures formed by interlaced fibers, making it more susceptible to air exposure and moisture absorption. During the impregnation process, the DCMC-gelatin-chitosan composite penetrated the fiber gaps, filling the original pores and forming a thin film that further covered residual micropores, resulting in a more uniform surface topography. Cross-sectional observations also indicate that the impregnation treatment effectively reduced the internal porosity of the parchment.

Fig. 1 SEM analysis of (a) Surface of the control sample (b) Surface of the modified sample (c) Cross-

section of the control sample (d) Cross-section of the

modified sample

As shown in Figure 2, compared with the control sample, the modified parchment exhibits an increase in hydrogen content and a significant decrease in nitrogen content. This is due to the abundance of hydroxyl and methylene groups in dialdehyde carboxymethyl cellulose, gelatin, and chitosan, while carboxymethyl cellulose contains no nitrogen[9-11]. In the infrared spectrum, the stretching vibration wavelengths of C=N and C=O, representing amide I and amide II bands, respectively, fall within the range of 1500 cm-1 to 1700 cm-1 [12-13]. Both amide I and II bands of the modified parchment show slight shifts, indicating the occurrence of cross-linking reactions [14].

Further analysis by XPS spectra (Figure 3) revealed a distinct characteristic peak of O-C=O at 288.81 eV in the modified parchment, which was not observed in the control sample. This confirms the introduction of abundant carboxyl groups from carboxymethyl cellulose, demonstrating the successful incorporation of the composite film. The emergence of a new peak at 398.91 eV indicates the occurrence of a Schiff base reaction between the aldehyde groups of DCMC and the amino groups present in both the parchment and the base solution, thereby forming a covalent crosslinked network[15].

Fig.2 Elemental analysis and FTIR spectra of parchment

Fig.3 XPS spectraÿControl samples of (a) C1s, (b) N1s, (c) O1s, modified samples of

(d) C1s, (e) N1s, (f) O1s.

3.2 Performance and Reliability Evaluation of Modified Parchment

As shown in Figure 4, the data were analyzed using a t-test in Excel. Compared with the control sample, the modified parchment exhibited a significant increase in tensile strength ($p < 0.05$) from 12.51 kN/m to 16.60 kN/m, and in tear index ($p < 0.05$) from 9.85 mN·m²/g to 10.47 mN·m²/g, indicating a notable enhancement in mechanical strength. This improvement is attributed to Schiff base reactions between dialdehyde groups and amino or hydroxyl groups of gelatin, as well as amino groups of chitosan, leading to

cross-linking. Similar phenomena have been observed in glutaraldehyde-crosslinked, heat-cured, or UV-treated collagen films[16].Compared to the control, the modified parchment showed significant reductions ($p < 0.05$) in water vapor permeability (18.06%), water absorption (14.31%), and Cobb value (8.95%), indicating improved barrier properties. Both the control and modified parchment significantly reduced ($p < 0.05$) the moisture content of packaged salt compared to unpackaged tests, with the control at 0.37% and the modified sample at 0.21%—a reduction of 43.24% for the modified parchment, demonstrating enhanced moisture resistance.The total

oxidation value of castor oil packaged with unmodified parchment and the control was significantly lower ($p < 0.05$) than that of unpackaged oil, with the control at 1.8 and the modified sample at 1.4—a reduction of 22.22% for the modified parchment, indicating improved antioxidant properties. The yellowing resistance grade, rated on a scale of 1–5, improved to 3–4 for the modified parchment compared to the unmodified sample, suggesting enhanced anti-yellowing performance. Additionally, the heavy metal migration levels for both the control and modified parchment were well below 1 mg/kg, meeting safety standards.

Fig. 5 (a) Performance and reliability

evaluation of parchment

4. Conclusion

A dialdehyde carboxymethyl cellulose-gelatin-chitosan base solution was prepared and used to impregnate parchment for performance enhancement. Comparison between the unmodified and impregnated parchment revealed that the impregnation treatment resulted in a smoother surface. Through Schiff base reactions between the dialdehyde groups and amino groups, a rigid film structure was formed, leading to significant improvements in the physical and barrier properties of the parchment. The modified parchment achieved a tensile strength of 16.60 kN/m, a tear index of 10.47 mN·m²/g, and a water

vapor permeability of 0.059 mg/(cm²·h). In moisture resistance tests, the moisture content of salt packaged with the modified parchment was reduced by 43.24% compared to the control sample. In water resistance tests, the Cobb value of the modified parchment decreased by 7.6 g/m² relative to the control. In antioxidant experiments, the total oxidation value of castor oil in contact with the modified parchment was reduced by 22.22% compared to the control. Furthermore, the yellowing resistance of the parchment was notably improved after modification. Therefore, impregnation with the dialdehyde carboxymethyl cellulose-gelatin-chitosan base solution effectively enhanced the performance of parchment, demonstrating its potential for future applications as a highstrength and highly environmentally reliable biomass-based packaging material.

References

1. ZHANG Y, LI S, WANG X, et al. Property of

Parchment Paper based on the WB600-KerT Enzyme Unhairing [J]. Leather Science and Engineering, 2024, 34(03): 73-79.

2. YANG S, GONG Y, CHEN, YING WU, et al.

Parchment Replicating with Leather Technology [J]. Leather Science and Engineering, 2021, 22(04): 16-19.

3. HUANG M Y. Study on Adsorption of Heavy

Metal Ions by Tannin-Dialdehyde Carboxymethyl Cellulose [D]; Guangxi University, 2022.

4. ZHANG H Q. Hubei University of Technology

[D]; Hubei University of Technology, 2019.

5. LIU J Y, LIU X L, XIA W S. Effects of Modified

Nanoparticles Loaded with Eugenol on Properties of Zein Films [J]. Journal of Food Science and Technology, 2023, 41(05): 123-135.

6. TANG S, BULATOV V, SCHECHTER I, et al.

Parchment characterization by multiphoton electron extraction spectrometry [J]. Archaeometry, 2021, 64(2): 468-482.

7. MU C, GUO J, LI X, et al. Preparation and

properties of dialdehyde carboxymethyl cellulose crosslinked gelatin edible films [J]. Food Hydrocolloids, 2012, 27(1): 22-29.

8. LIU Y, LI D G. Determination on Migration

Magnitude of Heavy Metal in Paper Base Straw by Inductively Coupled Plasma [J]. China Paper Corporation, 2022, 43(06): 37-39.

9. YING Y, XIAO X J, CHEN Y, et al. Research

Progress on Carboxymethyl Cellulose [J]. Guangzhou Chemical Industry, 2024, 52(22): 31-34.

10. WANG X C, ZHAO W Y, ZHANG H J.

fö€„v9e‘‘ÊSvQ(Wö€ÏžBR-N„v”^(u—xvzÛ U\ [J]. Journal of Shaanxi University of Science & Technology, 2022, 40(04): 100-108.

11. LEI H B, ZHANG C, WHANG H D, et al.

Research progress of chitosan-based dye adsorbents [J]. College of Basic Science,Tianjin Agricultural University, 2025, 32(04): 78-85.

12. YU S C, LAI Z H. Study on Extraction

Technology and Properties of Gelatin from Golden Pompano Bones [J]. Food Research and Development, 2020, 41(03): 159-165.

13. LI L Q, CHEN X F, LIU N, et al. Preparation

and characterization of apple pomace oxidized cellulose [J]. Food and Fermentation Industries, 2018, 44(02): 129-134.

14. XU H Y, LI W Z, ZHAO M Z, et al. Preparation

and characterization of 2,3-dialdehyde cellulose/ gelatin film [J]. Food and Fermentation Industries, 2022, 48(12): 75-81.

15. MA Y, YAO J, LIU Q, et al. Liquid Bandage

Harvests Robust Adhesive, Hemostatic, and Antibacterial Performances as a First Aid Tissue Adhesive [J]. Advanced Functional Materials, 2020, 30(39): 2001820.

16. WEADOCK K, OLSON R M, SILVER F H.

Evaluation of collagen crosslinking techniques [J]. Biomaterials, medical devices, and artificial organs, 1983, 11(4): 293-318.