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Original Research Article

Edible Film-forming potential of Gelatin Blends With Glycerol and Sorbitol for Application in Instant Noodle Seasoning Powder Packaging

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ABSTRACT

This study aimed to investigate the potential of edible films made from gelatin combined with glycerol and sorbitol, and to apply these films to the packaging of instant noodle seasoning powder. Films were formed by dissolving gelatin at concentrations ranging from 4% to 8% (w/v) in a plasticizer mixture composed of glycerol and sorbitol at 25% (w/w). The dissolution was carried out at 55 °C for 30 minutes. Mechanical strength, weld strength, and film solubility were measured to evaluate the quality of the films. The study found that the best film formation was achieved by combining 8% gelatin with a 25% (w/w) glycerol-sorbitol mixture in an 80:20 ratio. The resulting film exhibited excellent tensile strength of 156.28 MPa, weld strength of 27.11 MPa, and hot water solubility of 96.57%. The film was then applied to the packaging of instant noodle seasoning powder, which demonstrated good preservation of the noodles' structure and quality after 50 days of storage. This study provides an overview of the potential of combining various materials to create edible films for sustainable and environmentally friendly packaging.

Keywords: Edible film, Gelatin, glycerol, sorbitol, Packaging, Instant noodle seasoning powder packaging

Introduction

The non-biodegradable nature of polyethylene significantly contributes to environmental hazards associated with the growing accumulation of plastic waste.[1] Plastic has become a crucial component of the global economy and plays a significant role in the packaging industry. Nowadays, plastic packaging is extensively used in the food sector because it serves multiple functions, the most important of which is reducing food waste.[2] Worldwide, recycling rates for single-use plastic packaging remain low, with merely 14% of plastic packaging collected for recycling, and only 5% of this amount effectively processed into new plastic products.[3] Another significant concern regarding the use of plastic materials is their persistence in the environment due to their non-biodegradable nature.[4] Most synthetic plastics are utilized in the production of packaging, including food packaging.[5] Currently, various solutions have been proposed to minimize the environmental impact of plastic packaging. Among these, the method that has received the most attention is reducing the amount of material used by creating thinner packaging;[2] however, this approach has not been fully successful. Therefore, biodegradable packaging materials or films offer new avenues that can be explored to address this crisis.[5]

The development of environmentally friendly and sustainable packaging materials has become increasingly important in response to the negative environmental impacts of non-recyclable, petroleum-based plastic materials.

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Biodegradable packaging materials can be developed using macromolecules such as polysaccharides and proteins. Polysaccharides employed for this purpose include starch,[6] cellulose derivatives,[7] gums,[8] chitosan,[9] and alginate.[10] Similarly, proteins like whey protein,[6] gelatin,[11] and soy protein[12] have been utilized. Currently, edible films and packaging derived from these materials are used to preserve various food products, including fruits, nuts, confections, cheese, and fresh meat.

Protein-based edible films are formed by dissolving proteins in a solvent, which leads to the establishment of various bonds, including hydrophobic, hydrophilic, ionic, and covalent bonds between protein molecules and the solvent. As a result, these films possess strong mechanical properties and serve as effective barriers against gases such as O_2, CO_2, and N_2.[13] However, due to the inherently hydrophilic nature of protein molecules,[14] these films exhibit a high affinity for moisture. This hydrophilic characteristic results in high water vapor permeability, rendering them poor barriers against water vapor. Initially, water vapor and air molecules permeate the film layer, followed by the diffusion of water vapor through the film, and ultimately, condensation and release of water vapor on the opposite side. These processes lead to alterations in the physical properties and structure of the film, which in turn affect the quality of the enclosed food and cause deformation of the packaging, thereby promoting the growth of spoilage microorganisms.[15,16]

Due to their hydrophobic nature, lipids confer excellent moisture barrier properties to lipid-based edible films. However, these films are structurally brittle and exhibit poor mechanical strength and elasticity.[15,17]

Edible films fabricated from single materials inherently possess limitations that may not meet optimal requirements. To maintain the freshness of meat, an edible membrane must prevent moisture loss while allowing gas exchange; however, for cooked meat products, gas exchange must be completely inhibited. Films composed of proteins and polysaccharides exhibit good mechanical strength, but their high-water vapor permeability limits their applications. Therefore, combining different materials can yield films with desired properties suitable for preserving various food products. For instance, a combination of proteins or polysaccharides with lipids can produce films with high mechanical strength and excellent moisture barrier properties.[17]

This research aims to develop an edible film that can function as packaging, with the goal of reducing waste generated by plastic packaging and mitigating its negative impact on the environment. This study opens new research avenues in the field of food packaging, enhancing product convenience and shelf life without the use of preservatives, while also reducing the reliance on plastic packaging and contributing to environmental preservation.

Materials and methods

Experimental design

The ability of gelatin to form edible films in combination with glycerol and sorbitol was evaluated by examining the following factors:

Gelatin concentration: 4 - 8% (w/v)[18]
Glycerol concentration: 0 - 100% of 25% plasticizer (w/w)[19]
Sorbitol concentration: 0 - 100% of 25% plasticizer (w/w)[19]

The following factors were kept constant:

Dissolution temperature: 55 ºC[20]
Dissolution time: 30 minutes[20]

Table 1 presents the specific methods used to fabricate the film used in this study. Each experiment was repeated three times.

Table 1: Experimental design

Samples	Gelatin concentration (w/v)	25% plasticizer (w/w)	
		Glycerol concentration (w/w)	Sorbitol concentration (w/w)
M1	4	0	100
M2	4	20	80
M3	4	40	60
M4	4	60	40
M5	4	80	20
M6	4	100	0
M7	6	0	100
M8	6	20	80
M9	6	40	60
M10	6	60	40
M11	6	80	20
M12	6	100	0
M13	8	0	100
M14	8	20	80
M15	8	40	60
M16	8	60	40
M17	8	80	20
M18	8	100	0

Film forming process

The gelatin film combined with plasticizers (glycerol combined with sorbitol) was fabricated based on the description by Thomazine et al. (2006)[19] and Kozłowska et al. (2023),[21] with modifications. The gelatin and plasticizers (a combination of glycerol and sorbitol) were dissolved in distilled water according to the predetermined formula (Table 1), and the solution was heated to 55 °C for 30 minutes. The prepared solution was uniformly spread onto 6 x 13 cm mica discs and allowed to dry under laboratory conditions for 24 hours. After drying, the films were peeled off and stored in polyethylene (PE) bags at room temperature. Prior to measuring the specified parameters or using the membrane for seasoning packaging, the membrane was placed in a desiccator for approximately one hour.

Analytical methods

The mechanical strength of film: The mechanical strength of the film was evaluated by measuring its tensile strength using a ZwickRoell structural testing machine (ZwickRoell Ltd., Ulm, Germany), following the ASTM D3039 standard procedure as described by Engler et al. (2023),[22] with modifications. Test specimens measuring 20 x 120 mm were subjected to a uniaxial tensile force at a constant speed of 5 mm/min.

The hot water solubility: the solubility of the film in hot water was assessed by calculating the ratio of the weight of dry insoluble material to the initial weight of the sample. A modified method based on Ozdemir et al. (2008)[23] was employed to assess the solubility of films in hot water. The films were cut into 20 mm × 20 mm squares and dried at 100 °C for 24 hours. After drying, the films were weighed to a precision of 0.0001 g to determine their initial dry weight. Each film sample was then immersed in 20 mL of hot water and agitated in a shaking water bath for 5 minutes. Following this, the films were removed and dried again at 100 °C for another 24 hours to measure their final dry weight. Each sample was tested in triplicate, and the percentage of total soluble matter was calculated from the initial and final dry weights, reported on a dry weight basis.

Heat solderability: a sample with dimensions of 20 × 120 mm was divided into two equal sections. The two sections were then joined using an automatic bag sealing machine (FR770, Vietnam) to create a film sample with dimensions of 20 × 100 mm, featuring a welded seam at the midpoint. The bonding strength of the welded seam was evaluated by measuring the tensile force required to separate or rupture the seam under a coaxial tensile load at a rate of 100 mm/min.

Moisture absorption: Moisture absorption was determined according to the method described by Wang et al. (2005)[24], with modifications to accommodate the experimental samples. Specifically, moisture absorption was calculated as the ratio of the mass of the sample (either the seasoning powder packaging or squeezed instant noodle) after the observation period to its initial mass. For seasoning sachets directly exposed to the environment, measurements were taken every two days, whereas for those in contact with compressed instant noodles inside plastic packaging, measurements were taken every five days. The experiments were conducted in triplicate, using initial samples of seasoning powder packaging and squeezed instant noodles weighing 5.3 g and 25 g, respectively.

Statistical analysis

The experiments were performed using a randomized design, with one or two factors varied and each condition replicated three times. Results are reported as mean ± standard deviation (SD) and were statistically evaluated using one-way analysis of variance (ANOVA). Tukey's test was employed for mean comparisons relative to the control group, with statistical significance set at $p < 0.05$. Data analysis will be conducted using R statistical software.

Results and Discussions

The edible film-forming ability of gelatin, when combined simultaneously with glycerol and sorbitol, was evaluated. The assessment focused on tensile strength, heat sealability, and hot water solubility of the resulting edible films. These films were composed of gelatin-glycerol-sorbitol mixtures, with gelatin concentrations ranging from 4% to 8% (w/v) and a fixed plasticizer concentration of 25% (w/w). The plasticizer consisted of varying proportions of glycerol and sorbitol, each ranging from 0% to 100% (w/w).

Mechanical properties of the film

Tensile strength

The ANOVA analysis results demonstrated a statistically significant difference in tensile strength among the samples (p-value < 0.05) (Figure 1). At a constant plasticizer concentration, tensile strength of the films increased with higher gelatin concentrations. Specifically, at a plasticizer concentration of 25% (glycerol-to-sorbitol ratio of 0:100), the tensile strength rose from 147.31 Mpa to 188.44 Mpa as gelatin concentration increased from 4% to 8%. When gelatin concentration was held constant, the addition of plasticizers tended to reduce film tensile strength, with glycerol having a more pronounced effect than sorbitol. For instance, at a gelatin concentration of 4% with 25% plasticizer (glycerol-to-sorbitol ratio of 0:100), the film exhibited a tensile strength of 147.31 MPa; however, with a glycerol-to-sorbitol ratio of 100:0, tensile strength dropped to 49.77 MPa. The study of the physical properties of gelatin-based edible films with combined glycerol and sorbitol plasticizers confirmed that glycerol has a greater impact on reducing mechanical tensile strength than sorbitol.[19]

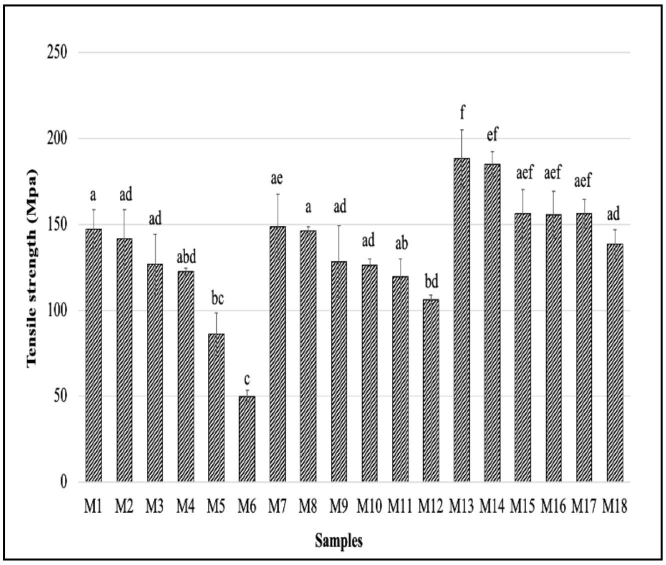

Figure 1: Tensile strength of gelatin – glycerol – sorbitol film (MPa; mean ± SD). Different letters indicate statistically significant differences ($p < 0.05$)

Strength of the heat-sealed joint

Figure 2 illustrates the effect of varying concentrations of gelatin and sorbitol on the strength of heat-sealed joints in gelatin-glycerol-sorbitol edible films.

The strength of the heat-sealed joint is positively correlated with gelatin concentration. Specifically, under consistent plasticizer conditions with a 25% concentration (glycerol-to-sorbitol ratio of 0:100), the tensile strength of the welds increased from 3.52 Mpa to 17.8 Mpa as the gelatin concentration rose from 4% to 8%. Thomazine *et al.* (2006)[19] demonstrated that glycerol has a more pronounced plasticizing effect than sorbitol. Consequently, at a given gelatin concentration, the strength of the heat-sealed joint improves as the proportion of glycerol increases relative to sorbitol. As illustrated in Figure 2, the gelatin-glycerol-sorbitol film with 4% gelatin and a glycerol-to-sorbitol ratio of 0:100 exhibited a lower tensile strength in the heat-sealed joint (3.52 Mpa) compared to a ratio of 100:0 (6.66 Mpa).

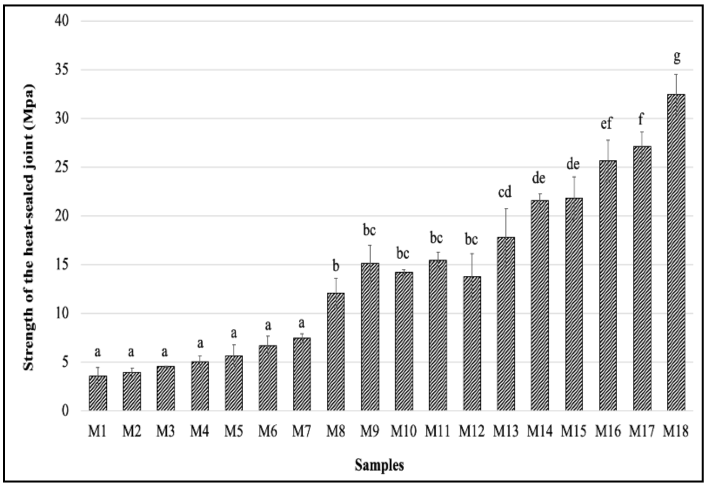

Figure 2: The strength of the heat-sealed joint of gelatin – glycerol – sorbitol film (MPa; mean ± SD). Different letters indicate statistically significant differences ($p < 0.05$)

Solubility in hot water

The edible films derived from gelatin in combination with glycerol and sorbitol demonstrated high solubility in hot water at 95°C, with values ranging from 94.9% to 96.79% (Figure 3). This elevated solubility in hot water can be attributed to the interaction between gelatin and the hydrophilic agents glycerol and sorbitol, both of which possess significant moisture absorption capacity.

According to the results shown in Figure 1, M13, M14, and M17 demonstrated the highest tensile strength, although the differences among them were not statistically significant. In Figure 2, M16, M17, and M18 achieved the highest tensile strength in welds, but there was no significant difference observed among these samples. Overall, M17 exhibited the optimal performance in terms of both weld strength and mechanical stress, achieved with a gelatin concentration of 8% and a plasticizer concentration of 25%, using a glycerol-to-sorbitol ratio of 80:20.

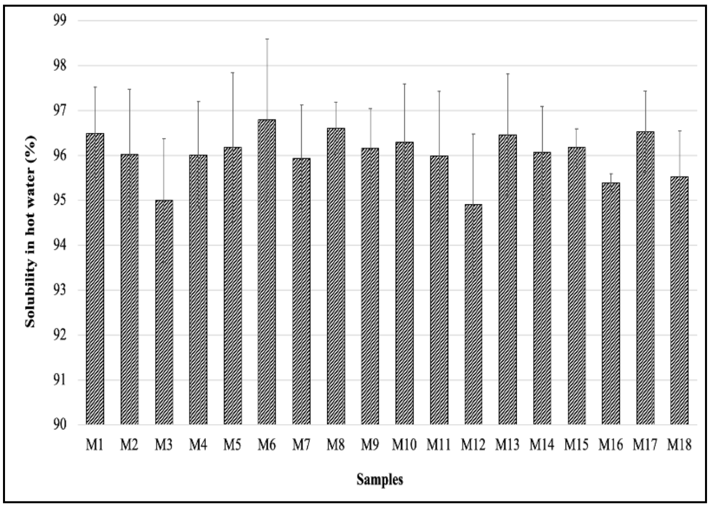

Figure 3: Solubility in hot water of gelatin – glycerol – sorbitol film (%; mean ± SD)

The application of edible films for seasoning powder packaging in instant noodles

Edible films composed of gelatin, glycerol, and sorbitol (GGS) with a gelatin concentration of 8% and a plasticizer concentration of 25% (glycerol-to-sorbitol ratio of 80:20) were utilized in experiments to assess their suitability for packaging seasoning powder in instant noodles.

Case 1: Changes of seasoning powder packaging in direct contact with ambient environment

Table 2 and Figure 4 illustrate the weight gain of seasoning powder packaging made from gelatin-glycerol-sorbitol (GGS) when exposed to ambient environmental conditions. When placed in direct contact with the surrounding environment, the weight of the packaging increased significantly due to the hydrophilic nature of the material and the relatively high ambient humidity (70 - 80%) compared to the initial moisture content of the film. Consequently, hydration occurred in the structural components of the film, facilitating the exchange of water vapor and air through the membrane, which led to an increase in the weight of the seasoning powder packaging.

Table 2: The weight gain of the seasoning powder packaging gelatin-glycerol-sorbitol in direct contact with ambient environment

Storage time (days)	Weight gain (%)	Appearance state
2	0.882	The packaging is dry, no strange smell
4	1.316	
6	11.916	The packaging is a bit soft, no strange smell
8	12.430	
10	–	The packaging is soft, sticky, not intact, no strange smell

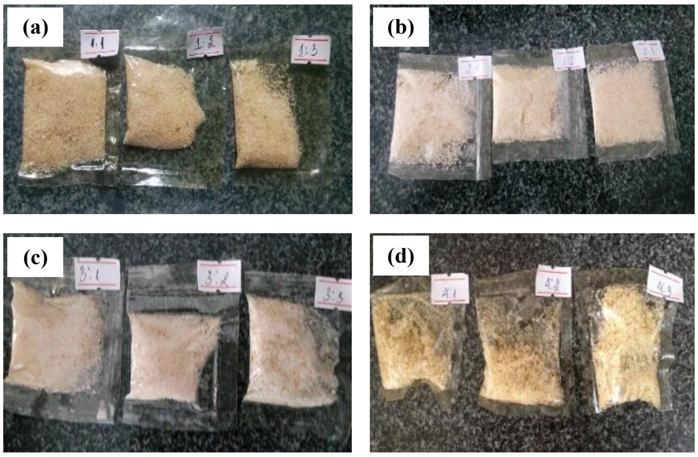

Figure 4: Visual state of the seasoning powder packaging GGS in direct contact with the ambient environment after 8 days of storage. (a) after 2 days; (b) after 4 days; (c) after 6 days; (d) after 8 days of storage.

Overall, the optimal films selected from the experiment retained their structural integrity and remained odorless when used for seasoning powder packaging in direct contact with the ambient environment for a duration of 8 days. However, the weight of the packaging increased progressively over the storage period due to the high environmental humidity, which promoted water absorption. Notably, during the first 4 days of storage, the weight of the packaging increased gradually, whereas, in the subsequent 4 days, a significant increase in weight was observed. By the 10th day of storage, the packaging had become soft, sticky, and structurally compromised, making it impossible to measure their weight accurately. These findings indicate that GGS films, when exposed to ambient conditions, have a limited shelf life and are unsuitable for long-term food packaging applications.

Case 2: Changes of the seasoning powder packaging when applied in instant noodle

Table 3 and Figure 5 illustrate the changes in weight and visual appearance of both the seasoning powder packaging and the squeezed instant noodle.

Table 3: Changes of the seasoning powder packaging and the squeezed instant noodle

Storage time (day)	Weight loss of the seasoning powder packaging (%)	Weight gain of the squeezed instant noodle (%)
5	4.354	0.234
10	6.482	0.420
15	6.293	0.463
20	6.703	0.488
25	6.420	0.633
30	5.571	0.573
35	5.461	0.606
40	5.196	0.531
45	4.563	0.509
50	4.447	0.490

During the experiment, a moisture exchange between the seasoning pouches and the noodles was observed. Initially, both the weight loss of the seasoning powder packaging and the weight gain of the compressed instant noodles increased gradually to a peak value before subsequently decreasing and stabilizing toward the end of the experiment. Within the first 20 days, the weight loss of the seasoning powder packaging rose steadily to 6.703% on day 20, after which it declined and stabilized at approximately 4.447% by day 50. Similarly, the weight gain of the compressed instant noodles gradually increased to 0.488% on day 20, followed by a slight decrease, stabilizing at 0.49% by day 50.

The results of the 50-day experiment demonstrate that GGS film effectively preserves the seasoning powder and maintains product quality. The seasoning powder packaging remained dry and intact, while the compressed instant noodles retained their hardness and crispiness.

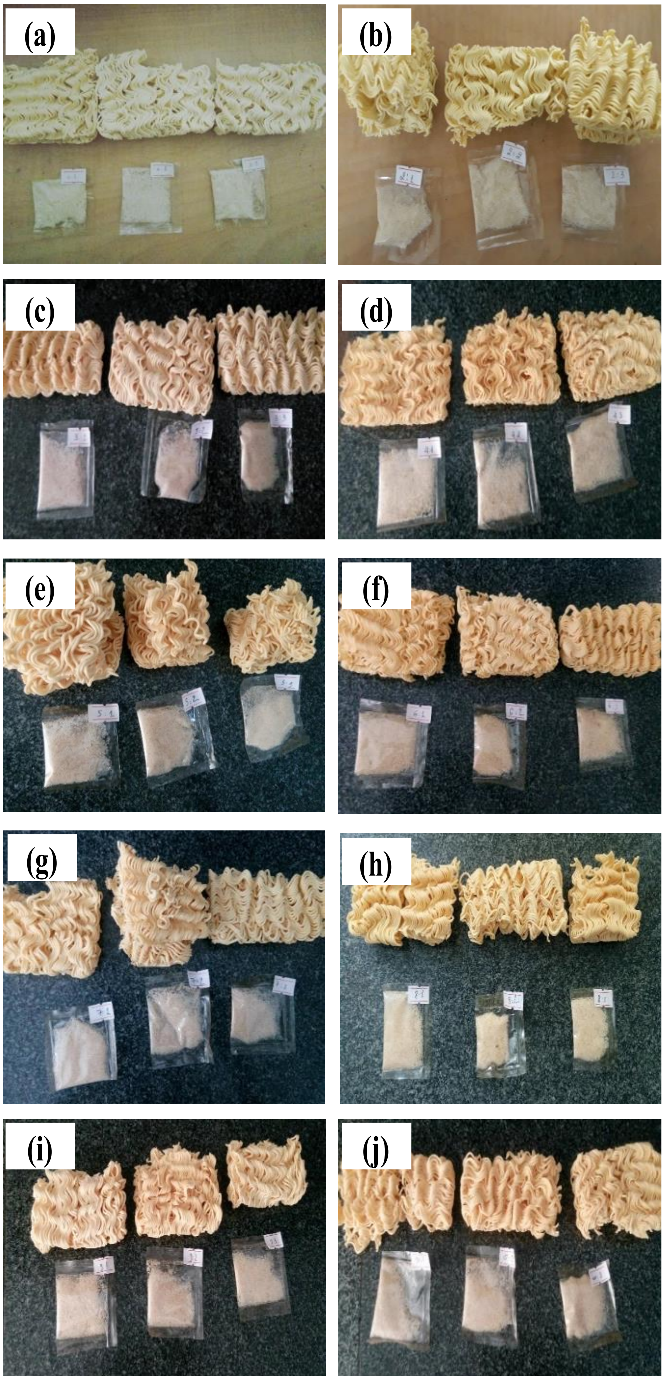

Figure 5: Visual condition of the seasoning powder packaging and the squeezed instant noodles when applied in instant noodle after 50 days of storage. (a) after 5 days; (b) after 10 days; (c) after 15 days; (d) after 20 days; (e) after 25 days; (f) after 30 days; (g) after 35 days; (h) after 40 days; (i) after 45 days; (j) after 50 days of storage.

Conclusion

The formation of gelatin film for seasoning powder packaging in instant noodles was conducted using an 8% gelatin solution combined with a glycerol plasticizer mixture at a 25% (w/w) concentration in an 80:20 ratio. This film demonstrated significant mechanical strength with a tensile strength of 156.28 MPa and a weld strength of 27.11 MPa, alongside a hot water solubility of 96.57%. The GGS film, when utilized to package seasoning powder at a weight of 5.3 g, performed differently under various storage conditions. While the packaging absorbed moisture and softened within eight days in a room environment, it remained intact and odorless for over 50 days when stored in plastic alongside compressed instant noodles, which also retained their structure and quality. This indicates the potential for using hydrophobic compounds in future research to further enhance the film's properties by reducing its hygroscopicity without compromising its solubility.

Conflict of Interest

The authors declare no conflict of interest

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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