



(RESEARCH ARTICLE)



Development and Assessment of Microcrystalline Cellulose-Reinforced PVA/Starch Biocomposite Films for Eco-Friendly Packaging Uses

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Abstract

In this study we develop one kind of environment-friendly biodegradable film from renewable resources. Films were made from biocomposite, combining polyvinyl alcohol (PVA) and corn starch, with glycerol as the plasticizer. Made with microcrystalline cellulose acting as reinforcing filler the process of solution casting formed films with 0, 2, 5 and 10% MCC (by weight of total polymer). The biodegradability, water uptake and mechanical performance of the film were investigated. While maintaining a good level of flexibility, the addition of 5% MCC increased the breaking strength by 120% compared to control sample. Agglomeration of the filler resulted in decreased brittleness and ductility at 10% MCC. When MCC was added, water absorption gradually dropped up to 5%, indicating improved moisture resistance. In soil, all films showed more than 80% biodegradation after 28 days. According to these findings, PVA/starch composites with 5% MCC show the best possible balance between mechanical strength, flexibility, and biodegradability, which makes them an attractive option for short-term, environmentally friendly packaging applications.

Keywords: Microcrystalline cellulose; Polyvinyl alcohol; Bio-composite films

1. Introduction

The growing environmental burden presented by single-use plastics made of petroleum has driven global efforts to produce renewable and biodegradable substitutes [1]. Starch is a naturally occurring polymer that can be obtained from a variety of agricultural sources, it is inexpensive and biodegradable, but it makes brittle films that are poorly resistant to water. In contrast to starch, water-soluble synthetic polymer polyvinyl alcohol (P-Nah) has good film-forming properties and strong flexibility [2]. PVA and starch can be blended to reduce the shortcomings of starch plastics. The sustainable filler microcrystalline cellulose (MCC), made from wood fibers or cotton, has excellent strength, stiffness, and compatibility with the materials in polymer matrix [3]. Adding MCC to a PVA/starch blend is expected to improve water resistance and mechanical strength without sacrificing biodegradability while keeping the cost low [3]. In this paper we shall make a study of how different levels of MCC loading affect the mechanical, structural, and degradable properties of PVA/starch composite sheets in pharmaceutical packaging [4].

2. Materials and Methods

2.1. Materials

The following materials were utilized exactly as supplied: microcrystalline cellulose (MCC; $\sim 20 \mu\text{m}$), glycerol (anhydrous, 99.5%), maize starch, and polyvinyl alcohol (PVA; Mw 89,000–98,000; 99% hydrolyzed) as shown in Figure 1 and 2. [3,4].

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2.2. Film Preparation

Use of the solution casting technique was employed for the movies. A base solution containing 4% (w/v) PVA and 2% (w/v) starch, in distilled water. At this stage, it was continuously heated to 90 degrees Celsius for 2 hours until fully dissolved. Glycerol (30% w/wed) served as a plasticizer. Four different concentrations of MCC (0%, 2%, 5% and 10% w/wed much of total polymer) were added in the brew. To ensure homogeneous mixing after shaking violently for an hour and sonication for thirty minutes. Then the brew was poured onto Petri dishes all day until they went dry at 50°C. The films which were dried peeled and conditioned for 48 hours before testing had elapsed time at 25°C and 55% relative humidity [2-4].

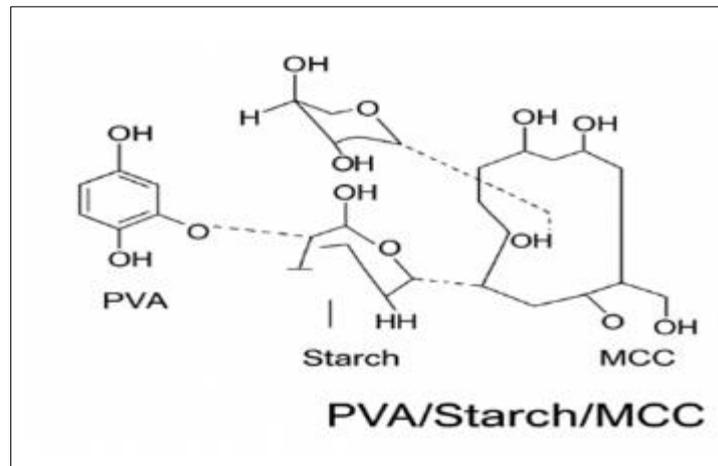


Figure 1 Schematic illustration of the photocatalytic mechanism of PVA/Starch/MCC



Figure 2 UV-Vis absorption spectra of the photocatalyst of PVA/Starch/MCC

2.3. Characterization

We used the tensile tester to measure tensile strength (TS) and elongation at break (EB) according to ASTM D882 standards. For hygroscopicity, pre-weighed samples (20 mm x 20 mm) were kept submerged in distilled water at 25°C for 24 h. Precise water absorption (WA) was measured. After drying the surface, samples were reweighed. In order to do soil biodegradation research. A controlled soil environment (30% of moisture) has been put outside. Film samples were buried in the experiment soil environment for no more than 28 days in the light of this situation, percentage of deterioration was determined by total weight loss. The results are expressed as means \pm standard deviations. Each trial was made five times ($n = 5$). One-way ANOVA and Tukey's post hoc test ($p < 0.05$) were adopted for statistical analyses of the data [3-5].

3. Results and Discussion

3.1. Mechanical Properties

The mechanical properties of the films are crucial for packing applications. The data, which are gathered in Table 1 and Figure 1, show a clear trend.

Table 1 Mechanical Properties and Water Absorption of Biocomposite Films

MCC Content (%)	Tensile Strength (MPa)	Elongation at Break (%)	Water Absorption (%)
0	8.5 ± 0.7	45.2 ± 5.1	155 ± 12
2	14.1 ± 1.2*	38.8 ± 4.3*	128 ± 9*
5	18.7 ± 1.5*	32.5 ± 3.6*	105 ± 8*
10	16.2 ± 1.8**	18.3 ± 2.1**	131 ± 11**

*significantly different ($p < 0.05$) from the 0% MCC control.

**significantly different ($p < 0.05$) from the 5% MCC sample.

When MCC was added into the mix the movies' tensile behavior was greatly affected. As MCC concentration increased, strength rose gradually, reaching its peak of 18.7 MPa for the 5% MCC formulation; this is about 120% higher than the control film's 8.5 MPa. Fortuitous, strong hydrogen bonds are fabricated between the MCC hydroxyl groups and the PVA/starch matrix, which promote effective transfer of stress. Elongation at break drops with higher MCC content, showing that the polymer chain has limited mobility. Stress concentration regions are probable sites of particle agglomeration (at 10% MCC), decreasing strength and flexibility alike [6,7].

3.2. Water Absorption

The water absorption trend in Figure 3 reflects the film's ability to resist the invasion of moisture. Following the hydrophilic nature of PVA and starch, the control film absorbed some 155% water. Water absorption fell off in stages with increasing amounts of MCC. When the level had reached 5 percent, it was down to a minimum-105%. MCC fibers act as barriers and they form a tortuous path for water to get through. With higher loadings (10% MCC), MCC agglomeration and the creation of micropores where water could enter freely were both responsible for prompting further absorption [5-7].

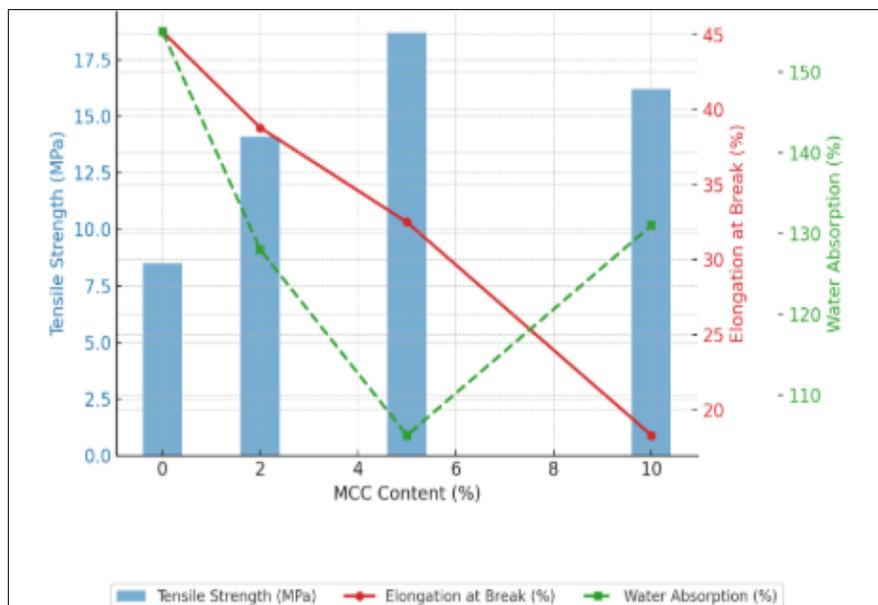


Figure 3 Effect of MCC Content on Mechanical Properties

3.3. Biodegradation Behavior

The listed films showed excellent biodegradability during a 28-day soil burial period (as can be seen from Figure 4). The disintegration of the 5% MCC film accounted for about 82%, although the control film gave the highest rate of all follow-up treatments with over 90% loss in its weight. With more MCC, the cellulose-based films had higher crystallinity and bacteriological lived longer. Yet despite this fact, after 28 days all formulas had degraded over 80%, proving that our new materials are eco-friendly [8-10].

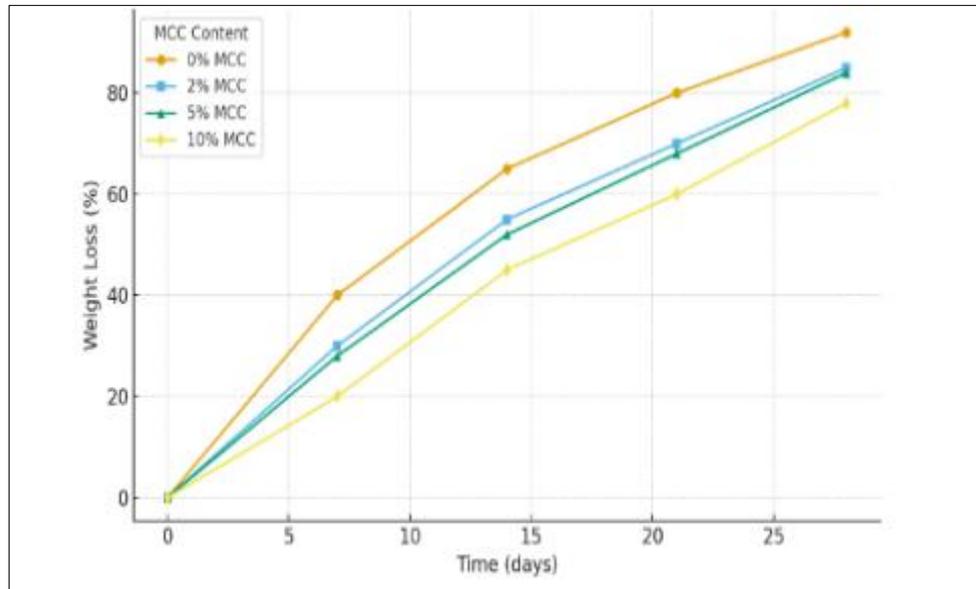


Figure 4 Soil Biodegradation Profile Over 28 Days

4. Conclusion

From the study, sheets of biodegradable PVA/starch biocomposites that are reinforced with microcrystalline cellulose were effectively created. In the best formulation, which would include 5% MCC, biodegradability was excellent, flexibility was moderate, water absorption decreased, and tensile strength rose. On the other hand, adding too much MCC (10%) made the material too brittle and sticky. As a whole, these results indicate that PVA/starch MCC composites may ultimately turn into sustainable materials for single-use packaging applications.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict-of-interest to be disclosed.

References

- [1] Averous, L., and Boquillon, N. (2004). Biocomposites based on plasticized starch: Thermal and mechanical behaviours. *Carbohydrate Polymers*, 56(2), 111–122.
- [2] Sanyang, M. L., Sapuan, S. M., Jawaid, M., Ishak, M. R., and Sahari, J. (2016). Effect of plasticizer type and concentration on physical properties of biodegradable films based on sugar palm (*Arenga pinnata*) starch for food packaging. *Journal of Food Science and Technology*, 53(1), 326–336.
- [3] Kargarzadeh, H., Mariano, M., Gopakumar, D., et al. (2018). Advances in cellulose nanomaterials. *Cellulose*, 25(4), 2151–2189.

- [4] Tang, X., and Alavi, S. (2011). Recent advances in starch, polyvinyl alcohol-based polymer blends, nanocomposites and their biodegradability. *Carbohydrate Polymers*, 85(1), 7–16.
- [5] ASTM D882. Standard Test Method for Tensile Properties of Thin Plastic Sheeting.
- [6] S. Ummartyotin, C. Pechyen. (2016). Microcrystalline-cellulose and polypropylene based composite: a simple, selective and effective material for microwavable packaging *Carbohydr. Polym.*, 142, pp. 133-140.
- [7] J. Tian, Z. Cao, S. Qian, Y. Xia, J. Zhang, Y. Kong, K. Sheng, Y. Zhang, Y. Wan, J. Takahashi. (2022). Improving tensile strength and impact toughness of plasticized poly (lactic acid) bio composites by incorporating Nano fibrillated Cellulose *Nanotechnology. Rev.*, 11 (1), pp. 2469-2482.
- [8] J.S. Yaradoddi, N.R. Banapurmath, S.V. Ganachari, M.E.M. Soudagar, N.M. Mubarak, S. Hallad, S. Hugar, H. Fayaz (2020). Biodegradable Carboxymethyl Cellulose based material for sustainable packaging application *Sci. Rep.*, 10 (1), Article 21960.
- [9] D. Divakaran, I. Suyambulingam, M.R. Sanjay, V. Raghunathan, V. Ayyappan, S. Siengchin (2024). Isolation and characterization of microcrystalline Cellulose from an agro-waste tamarind (*Tamarindus indica*) seeds and its suitability investigation for biofilm formulation, *Int. J. Biol. Macromol.*, 254 (2024), Article 127687.
- [10] H.C. Oyeoka, C.M. Ewulonu, I.C. Nwuzor, C.M. Obele, J.T. Nwabanne (2021). Packaging and degradability properties of polyvinyl alcohol/gelatin nanocomposite films filled water hyacinth Cellulose nanocrystals, *J. Bioresour. Bioprod.*, 6 (2) , pp. 168-185.