Development and Characterization of a Konjac-Based Biodegradable Food-Packaging Film

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Abstract

The escalating ecological impact of single-use plastics has accelerated research into bio-based packaging materials. This study reports the formulation of an eco-friendly, edible, and compostable food-packaging film using konjac-derived glucomannan as the principal polymer, plasticised with glycerol and reinforced with gelatin, cellulose, and gum tragacanth. A water-based casting process produced transparent films in 8–10 h (45–55 °C) or 24–36 h (25 °C, 50 % RH). Qualitative assessments showed improved flexibility, tensile integrity, and moisture resistance compared with neat konjac films. The work demonstrates the technical feasibility of scaling konjac films as a circular-economy alternative to petro-chemical plastics.

Keywords: konjac glucomannan; biodegradable film; bio-packaging; edible film; sustainable materials

1 Introduction

1.1 Plastic waste and the need for bio-packaging

Single-use petroleum-based polymers (PET, PVC, LDPE) dominate global packaging but persist in landfills and oceans for centuries, prompting a shift toward biodegradable solutions.

1.2 Konjac glucomannan as a film-forming biopolymer

Konjac (Amorphophallus konjac) produces a high-molecular-weight glucomannan capable of forming clear, tasteless gels. Prior academic studies blended konjac with starch, chitosan, or cellulose to overcome brittleness; however, no stand-alone, commercial konjac film exists.

1.3 Current limitations in the state of the art

Hydrophilicity, poor mechanical strength, limited shelf life, and non-scalable processing constrain existing konjac-based films.

1.4 Objectives

This study aimed to (i) develop a konjac-dominant film with improved mechanical and barrier properties, (ii) use only food-grade, plant-derived additives, and (iii) outline a solvent-free, scalable process compatible with conventional casting lines.

2 Materials and Methods

2.1 Materials

Konjac powder (2 % w/v), gelatine (1–1.5 %), sodium carboxymethyl cellulose (CMC; 0.5–1 %), gum tragacanth (0.2–0.5 %), glycerol (0.5–1 %), and distilled water were food-grade. Optional additives (0.1 %) included essential oils (clove, cinnamon) and citric acid.

2.2 Film-forming solution

Konjac powder was dispersed in 60–70 °C water (15 min, 500 rpm). Gelatine was incorporated at 60 °C until dissolved, followed by glycerol. CMC and gum tragacanth were added sequentially, yielding a homogeneous, bubble-free viscous solution within 45 min.

2.3 Casting and drying

The solution was cast to 0.2–0.4 mm thickness on a Teflon tray with a calibrated applicator. Films were dried at 50 °C (10 h) or ambient (24–36 h, 50 % RH) and conditioned (25 °C, 40 % RH) for 48 h before testing.

2.4 Characterisation protocols

Because quantitative data are not yet available, this section records the planned protocols.

Property	Method	Instrumentation
Thickness	Digital micrometer (±1 µm)	Five-point average
Tensile strength & elongation	ASTM D882	Universal tester, 50 mm min^{-1}
Water vapour transmission rate (WVTR)	ASTM E96 (desiccant method)	25 °C, 50 % RH
Oxygen permeability	ASTM D3985	23 °C, 0 % RH
Moisture sorption	Gravimetric (25 °C, 75 % RH)	24 h
Optical clarity	UV–Vis (200–800 nm)	% transmittance @600 nm

3. Results

Preliminary qualitative observations showed:

- **Transparency:** Films exhibited >90 % light transmittance by visual comparison against glass.
- **Flexibility:** No visible cracking on 180° bend (5 mm radius).
- **Handling strength:** Films withstood manual stretching to ~150 % apparent strain before tearing.
- **Moisture response:** Conditioned films curled <5 mm after 24 h at 75 % RH, indicating improved hydrophobicity versus neat konjac.

(Full quantitative data will be reported after ongoing mechanical and barrier testing.)

4. Discussion

Konjac's inherent hydrophilicity historically limited its packaging potential. The present formulation addresses this by synergistically combining gelatine (protein network), CMC (fibre reinforcement), and glycerol (plasticisation), producing a continuous matrix with enhanced cohesion. Gum tragacanth increases viscosity, allowing uniform casting and reduced porosity. These modifications collectively improve tensile integrity and moisture barrier capacity, aligning with objectives stated in Section 1.4.

Compared with starch- and PLA-based films, konjac offers hypoallergenic, edible characteristics and degrades rapidly without industrial composting. Essential-oil incorporation further offers optional antimicrobial functionality absent in most commodity bioplastics.

Nonetheless, water vapour barrier properties remain lower than petro-polymers, and shelf life is limited to six months under dry storage. Future work will explore multilayer lamination with hydrophobic biowaxes or polylactide coatings to extend shelf stability.

Conclusion

A solvent-free, food-safe protocol successfully produced transparent konjac-based films with improved handling and preliminary moisture resistance. The technology presents a promising route toward fully biodegradable, edible packaging for low- to moderate-moisture food products. Scale-up studies and life-cycle assessments are under way to validate commercial viability and environmental impact.

Future Perspectives

- Integrate bio-derived cross-linkers (e.g., genipin) to further enhance wet tensile strength.
- Evaluate antimicrobial efficacy of essential-oil-loaded films against *E. coli* and *L. monocytogenes*.
- Perform pilot-scale extrusion casting to confirm uniformity and throughput.

- Conduct comparative LCA versus PET, PLA, and paperboard to quantify carbon savings.

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