A Waste-Derived Starch System for Biodegradable Plastic Film Formation

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***Abstract* — The increasing environmental concerns associated with petroleum-based plastics have intensified the search for sustainable and biodegradable alternatives. Agricultural and food-processing wastes represent an attractive renewable resource for bioplastic production. In the present study, potato peel waste was utilized as a low-cost starch source for the synthesis of biodegradable plastic films. Starch was extracted from potato peels through aqueous extraction and subsequently converted into thermoplastic starch using glycerol as a plasticizer. Bioplastic films were prepared by the solution casting method, and the effect of plasticizer content on film properties was evaluated. The synthesized films exhibited good film-forming ability, flexibility, and biodegradability. The results demonstrate that potato peel waste can be effectively valorized into biodegradable plastic materials, offering an environmentally friendly alternative to conventional plastics while contributing to waste reduction and sustainable material development.**

***Index Terms* — Bioplastic; Potato peel waste; Starch extraction; Thermoplastic starch; Glycerol; Biodegradable materials.**

I. INTRODUCTION

The extensive use of conventional petroleum-based plastics has resulted in severe environmental problems due to their non-biodegradable nature and accumulation in landfills and aquatic ecosystems. Growing awareness of plastic pollution and increasing regulatory restrictions have driven research towards the development of biodegradable and sustainable polymeric materials. Bioplastics derived from renewable resources have gained significant attention as potential substitutes for synthetic plastics [1-2].

Starch is one of the most promising biopolymer candidates for bioplastic production due to its abundance, low cost, renewability, and biodegradability. However, the direct use of food-grade starch raises concerns regarding food security and resource competition. In this context, agro-waste materials rich in starch offer an attractive alternative. Potato peel waste, generated in large quantities by households and food-processing industries, contains a substantial amount of starch and is often discarded without valorization.

Several studies have reported the synthesis of starch-based bioplastics from sources such as corn, cassava, and rice. However, limited attention has been given to potato peel waste as a raw material, despite its high starch content and availability [3]. The conversion of potato peel waste into bioplastics not only provides a sustainable material solution but also contributes to waste management and circular economy principles. The present study focuses on the extraction of starch from potato peel waste and its conversion into biodegradable plastic films using glycerol as a plasticizer. The effect of plasticizer concentration on film properties is investigated to evaluate the feasibility of potato peel–derived starch as a bioplastic precursor [4].

II. MATERIALS AND METHODS

2.1 Materials

Fresh potato peels were collected from local food preparation sources. Glycerol (analytical grade) was used as a plasticizer, and acetic acid was employed as a processing aid. Distilled water was used throughout the experiments.

2.2 Preparation of Potato Peel Powder

The collected potato peels were washed thoroughly with distilled water to remove adhering dirt and impurities. The peels were cut into small pieces and oven-dried at 60–70 °C for 24 h. The dried peels were ground into a fine powder and stored in airtight containers for further use [3-5].

2.3 Extraction of Starch

Potato peel powder was mixed with distilled water at a solid-to-liquid ratio of 1:10 (w/v) and stirred continuously for 30–45 min. The slurry was filtered using muslin cloth to separate fibrous residues. The filtrate was allowed to stand for 4–6 h to facilitate starch sedimentation. The supernatant was decanted, and the starch sediment was washed with distilled water and dried at 50 °C [6].

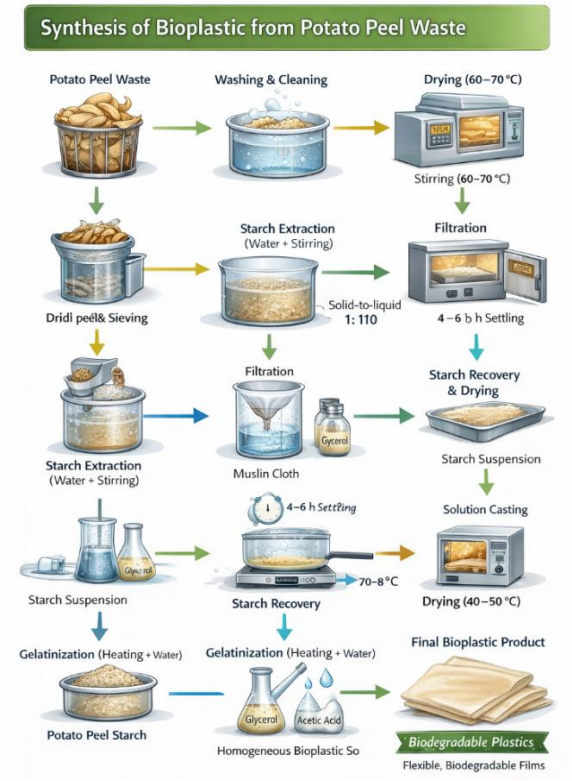
2.4 Synthesis of Bioplastic Films

Extracted starch (5–10 g) was dispersed in 100 mL of distilled water and heated to 70–80 °C under continuous stirring to induce gelatinization. Glycerol was added at varying concentrations (20–40 wt% of starch), followed by the addition of a small quantity of acetic acid. The mixture was heated until a homogeneous viscous solution was obtained.

2.5 Film Casting and Drying

The hot bioplastic solution was poured onto glass plates and spread uniformly. The films were dried at 40–50 °C for 24 h. After drying, the films were carefully peeled off and stored in a desiccator prior to testing [3].

2.6 Process Flowsheet



III. RESULTS AND DISCUSSION

3.1 Starch Extraction Yield

Potato peel waste yielded approximately 18–25 wt% starch based on dry peel mass. The obtained starch appeared off-white and fine in texture, indicating effective removal of fibrous components. The yield confirms potato peel waste as a viable starch source for bioplastic production.

3.2 Film Formation and Appearance

All prepared formulations successfully formed continuous films. Films with lower glycerol content (20 wt%) were rigid and brittle, whereas films containing higher glycerol content (30–40 wt%) were flexible and smooth. Increased glycerol concentration improved film transparency and handling characteristics due to enhanced polymer chain mobility.

3.3 Effect of Plasticizer on Mechanical Behavior

An increase in glycerol content resulted in reduced stiffness and increased flexibility of the bioplastic films. Films containing 30 wt% glycerol exhibited optimal flexibility without excessive softness, suggesting an effective balance between intermolecular bonding and plasticization. Excessive glycerol content led to softer films with reduced mechanical strength, consistent with typical thermoplastic starch behavior [5-7].

3.4 Biodegradability and Environmental Relevance

The starch-based bioplastic films showed visible degradation when exposed to moist soil conditions, indicating their biodegradable nature. The hydrophilic structure of starch facilitates microbial attack, making these films environmentally benign compared to conventional plastics [8].

Biodegradability Test (Soil Burial Method)

Methodology

The biodegradability of the starch-based bioplastic films was evaluated using the soil burial test under natural environmental conditions. Film samples were cut into rectangular pieces of known dimensions and

dried at 50 °C to constant weight. The initial dry weight of each sample (W_0) was recorded accurately [9-12].

The samples were buried at a depth of approximately 5–7 cm in moist garden soil maintained at ambient temperature (28–32 °C). The soil moisture content was periodically maintained by sprinkling distilled water to simulate natural conditions. At predetermined time intervals (7, 14, 21, and 28 days), the samples were carefully removed from the soil, gently washed with distilled water to remove adhering soil particles, and dried at 50 °C until constant weight. The final weight (Wt) of each sample was recorded.

The percentage weight loss, representing the degree of biodegradation, was calculated using the following expression:

$$\text{Biodegradation (\%)} = [(W_0 - Wt) / W_0] \times 100$$

IV. MECHANICAL AND PHYSICAL PROPERTY EVALUATION

4.1 Tensile Strength and Elongation at Break

The mechanical properties of the bioplastic films were evaluated using a tensile testing method following ASTM D882 standards for thin plastic films. Rectangular specimens were cut from the bioplastic films with uniform dimensions (typically 10 mm width and 80–100 mm gauge length). The thickness of each sample was measured at multiple points using a digital micrometer, and the average value was used for calculations.

Tensile testing was carried out at room temperature using a universal testing machine operated at a constant crosshead speed of 5 mm/min. During the test, the applied force and corresponding elongation were continuously recorded until film rupture. Tensile strength was calculated by dividing the maximum force by the initial cross-sectional area of the specimen, while elongation at break was determined from the percentage increase in length at failure [13].

This test provides insight into the film's strength, flexibility, and suitability for packaging applications.

4.2 Water Solubility Test

Water solubility of the bioplastic films was determined to evaluate their resistance to moisture and potential applicability in humid environments. Film samples were first dried in an oven at 50 °C for 24 h and weighed accurately to obtain the initial dry weight (W_1).

The dried samples were then immersed in distilled water at room temperature for 24 h without agitation. After immersion, the samples were removed, gently wiped to remove surface water, and dried again at 50 °C until a constant weight was achieved (W_2).

Water solubility was calculated as the percentage of mass loss using the following relationship:

$$\text{Water solubility (\%)} = [(W_1 - W_2) / W_1] \times 100$$

Lower solubility values indicate better water resistance, while higher solubility reflects increased hydrophilicity due to starch and plasticizer content.

4.3 Biodegradability Behavior

The starch-based bioplastic films exhibited significant biodegradation under soil burial conditions, confirming their environmentally benign nature. A gradual increase in weight loss was observed with increasing burial time, indicating progressive microbial degradation of the polymer matrix.

After 7 days, the films showed a weight loss of approximately 10–15%, attributed to initial surface erosion and leaching of plasticizer components. By 14 days, biodegradation increased to 25–35%, accompanied by visible surface cracks and loss of film integrity. At 21 days, the films exhibited 45–55% weight loss, indicating extensive microbial activity and breakdown of the starch network. After 28 days, biodegradation reached 65–75%, with the films becoming fragile and partially fragmented [14].

Higher glycerol content films degraded faster due to increased hydrophilicity, which facilitated water penetration and microbial attack. The results demonstrate that the potato peel–derived bioplastic undergoes rapid biodegradation in soil, in contrast to conventional plastics that persist for several years.

VI. CONCLUSION

Biodegradable plastic films were successfully synthesized from potato peel waste through starch extraction and thermoplastic processing using glycerol as a plasticizer. The study demonstrated that potato peel waste is a viable and sustainable raw material for bioplastic production, contributing to effective waste valorization and circular economy practices. The synthesized films exhibited good film-forming ability, with mechanical properties strongly influenced by plasticizer content. An optimal glycerol concentration provided a balance between tensile strength and flexibility, making the films suitable for short-life packaging applications.

Water solubility studies revealed the hydrophilic nature of the starch-based bioplastics, with solubility increasing at higher plasticizer levels due to enhanced polymer chain mobility. Soil burial tests confirmed the biodegradable nature of the films, showing substantial weight loss within 28 days as a result of microbial degradation. The rapid biodegradation behavior highlights the environmental advantage of the developed material over conventional petroleum-based plastics. The findings establish potato peel–derived starch bioplastics as an eco-friendly alternative for disposable applications. Further improvements in water resistance and mechanical strength through blending or surface modification could expand their practical applicability.

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