

An Experimental Study on Performance of Eco-Mulch Sheet from Banana Peels

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Abstract — The widespread use of conventional plastic mulch in agriculture has led to significant environmental challenges, including soil pollution, reduced fertility, and accumulation of non-biodegradable waste. Addressing these concerns, this study focuses on the development of a biodegradable mulch sheet derived from banana peel waste, an abundant agricultural byproduct rich in starch, cellulose, hemicellulose, and lignin. The preparation process involves collection of peels, thorough cleaning, sun-drying, and grinding into a fine powder. To enhance the quality of the mulch sheet, banana peel starch (liquid extract) and corn flour are incorporated as natural binding and reinforcing agents. Glycerin is added to improve flexibility, while vinegar (acetic acid) stabilises the mixture and prevents premature microbial degradation. The prepared mixture is heated under controlled conditions to form a homogeneous gel, which is then cast onto trays and dried to produce thin biodegradable sheets. Experimental evaluations confirm that the developed mulch sheet effectively conserves soil moisture, suppresses weed growth, and regulates soil temperature. It also undergoes natural decomposition within 30–60 days, releasing essential nutrients such as potassium, phosphorus, calcium, and organic carbon, thereby improving soil fertility. Compared to bare soil, the mulch sheet significantly enhances moisture retention and reduces weed growth. The findings demonstrate that banana peel-based mulch sheets, reinforced with natural starch sources, are cost-effective, eco-friendly, and sustainable alternatives to plastic mulch, promoting waste utilisation, reducing environmental pollution, and supporting green agricultural practices.

Keywords: Biodegradable mulch, Banana peel waste, Bioplastic, Soil fertility, Weed suppression, Sustainable agriculture.

I. INTRODUCTION

Agriculture plays a crucial role in ensuring food security and economic stability, particularly in developing countries such as India. Modern agricultural practice increasingly relies on mulching to conserve soil moisture,

regulate soil temperature, and suppress weed growth. Conventional mulch is dominated by polyethylene-based plastic films owing to their effectiveness and durability; however, their non-biodegradable nature has led to severe environmental problems, including soil contamination, reduced microbial activity, and disposal challenges. Plastic residues persist in soil for hundreds of years, and common disposal routes such as burning or landfilling further contribute to air pollution and greenhouse gas emissions [9], [24].

Biodegradable materials derived from renewable resources offer a promising alternative to plastic mulch. Bioplastics produced from plant-based polymers such as starch and cellulose decompose naturally through the action of bacteria and fungi, and are abundant, renewable, and environmentally safe [22]. Among agricultural residues, banana peel is particularly attractive: it contains approximately 18–20% starch along with cellulose, hemicellulose, and other nutrients, and is generated in very large quantities as household and agro-industrial waste in banana-producing countries such as India [26]. Converting this waste into a value-added bioplastic simultaneously addresses an organic-waste-disposal problem and yields a sustainable mulching material, eliminating the labour and cost associated with the removal and disposal of conventional plastic mulch.

Used as a mulch, a banana-peel-derived bioplastic sheet can suppress weed growth by blocking sunlight, conserve soil moisture by reducing evaporation, regulate soil temperature, and gradually decompose in the soil to release nutrients such as potassium, phosphorus, and organic carbon, thereby enhancing soil fertility. This study reports the development of such a biodegradable mulch sheet using banana peel powder reinforced with corn flour, plasticised with glycerin, and stabilised with vinegar, and evaluates its physical, mechanical, and functional performance. The specific objectives are to: (i) utilise banana peel waste for the production of biodegradable bioplastic material; (ii) develop a biodegradable mulch sheet from this material; (iii) characterise its physical

properties, namely thickness and flexibility; (iv) evaluate its water permeability for effective soil-moisture management; (v) analyse its soil-moisture-retention capability; and (vi) investigate its effectiveness in suppressing weed growth. By converting an agricultural by-product into a functional eco-mulch, this work contributes to sustainable development and supports environmentally responsible farming practices.

II. LITERATURE REVIEW

Extensive research has been carried out to identify economical, biodegradable alternatives to conventional plastic mulch. Kumar et al. [1] showed that agricultural waste rich in starch and cellulose can be converted into biodegradable films of acceptable mechanical strength through simple drying, grinding, and casting operations, while Gupta et al. [2] demonstrated specifically that banana peel can be processed into a flexible, biodegradable film using glycerin as a plasticiser. Sharma et al. [3] reviewed starch-based bioplastics and concluded that they are well suited to short-term agricultural applications, provided plasticisers and reinforcing agents are added to improve strength and flexibility. Rahman et al. [4] examined the role of glycerin in particular, reporting that it markedly improves flexibility and reduces brittleness, although an optimum dosage is required since excessive plasticiser reduces mechanical strength.

On the agronomic side, Singh et al. [5] reviewed mulching techniques and highlighted that, although plastic mulch is highly effective, its non-biodegradable nature necessitates alternative materials offering similar functional benefits. Wang et al. [6] reported that biodegradable mulch films perform comparably to plastic mulch in soil-moisture conservation and weed suppression while eliminating the need for post-season removal, and Verma et al. [7] confirmed that agro-wastes such as banana peel, rice husk, and corn starch can be valorised into eco-friendly, cost-effective biopolymers. Lee et al. [8] found that corn starch, owing to its high amylose content, is an effective film-forming and reinforcing agent, consistent with its use as a binder in the present study, while Das et al. [9] documented the long-term environmental damage caused by plastic mulch residues, including reduced soil microbial activity and air pollution from burning.

Several studies have examined the mechanical and degradation behaviour of bioplastics relevant to mulch applications. Patel et al. [10] showed that natural-fibre reinforcement improves the tensile strength and deformation resistance of bioplastics, and Iqbal et al. [11] established that starch-based bioplastics degrade within

weeks to months under soil conditions, releasing nutrients that improve fertility as they decompose. Joseph et al. [12] confirmed that banana peel, owing to its high starch content, is well suited for biodegradable film production, while Mehta et al. [13] and Ali et al. [14] respectively demonstrated that mulching significantly reduces evaporative water loss and suppresses weed germination by blocking light penetration to the soil surface.

Further supporting evidence comes from studies on waste utilisation and processing. Roy et al. [15] and Reddy et al. [16] reported that biodegradable materials derived from organic waste are environmentally safe, cost-effective, and improve soil structure and nutrient content. Khan et al. [17] emphasised that controlled heating is essential for proper starch gelatinisation and film formation, and Patel et al. [18] argued for a broader transition from conventional to eco-friendly agricultural materials. Nair et al. [19] discussed casting and drying techniques for biopolymer films, Singh et al. [20] examined value-added management of banana-peel waste, and Kaur et al. [21] showed that additives such as vinegar improve the stability of the mixture and inhibit microbial spoilage during preparation.

Collectively, the literature establishes that starch-rich agro-wastes — banana peel in particular — can be converted into flexible, biodegradable films using glycerin as a plasticiser and a mild acid such as vinegar as a stabiliser, and that such biodegradable mulch films perform comparably to plastic mulch in moisture conservation and weed suppression while avoiding its disposal problems [6], [23], [25]. However, most reported studies evaluate either bioplastic film properties or mulching performance in isolation, with relatively few studies integrating banana-peel-derived bioplastic specifically as a field-applicable mulch sheet subjected to combined physical, mechanical, and functional testing. The present study addresses this gap by developing a banana-peel/corn-flour mulch sheet and comprehensively evaluating its water permeability, moisture retention, biodegradability, thickness uniformity, and tensile strength.

III. MATERIALS AND METHODOLOGY

A. Materials

Banana peel powder, obtained from washed and oven-/sun-dried peels ground to a fine, sieved consistency, served as the base matrix material. It is naturally rich in starch (approximately 18–20%), cellulose, hemicellulose, and micronutrients such as potassium, phosphorus, and calcium, and contributes a major share of organic carbon

that is released into the soil as the sheet decomposes. Corn flour (70–75% starch, with 20–30% amylose and 70–80% amylopectin) was used as a natural binding and reinforcing agent; its high film-forming ability improves the strength, uniformity, and crack resistance of the cast sheet. Banana peel starch, recovered as a light-brown, viscous liquid extract during processing, supplied additional natural polysaccharides that improved the internal cohesion and homogeneity of the mixture.

Glycerin ($C_3H_8O_3$), a colourless, odourless, hygroscopic, and non-toxic liquid, was used as the plasticiser; it reduces brittleness and improves the flexibility and elasticity of the dried sheet. Vinegar, a dilute (4–8%) acetic-acid solution with a pH of 2–3, was added as a mild stabilising and antimicrobial agent to prevent spoilage of the mixture before drying. Water served as the solvent and mixing medium and was essential for uniform gelatinisation of the starches during heating. The role of each material is summarised in Table I.

TABLE I. MATERIALS USED AND THEIR FUNCTIONAL ROLE

Material	Function in the Mulch Sheet
Banana peel powder	Base matrix; releases nutrients on decomposition
Corn flour	Natural binder; improves strength and uniformity
Banana peel starch (liquid extract)	Improves cohesion and homogeneity
Glycerin	Plasticiser; imparts flexibility, resists cracking
Vinegar (4–8% acetic acid)	Stabiliser; antimicrobial during preparation
Water	Mixing and gelatinisation medium

B. Preparation of the Mulch Sheet

Fresh banana peels were collected, washed thoroughly to remove dirt and impurities, and dried — either under sunlight for 2–3 days or in an oven at 60 °C — until all surface moisture was removed. The dried peels were ground into a fine powder using a mechanical grinder and sieved to obtain a uniform particle size. A measured quantity of banana peel powder was combined with corn flour and water to form a smooth slurry, which was stirred continuously to prevent lump formation. Glycerin and vinegar were then added in measured proportions as the plasticising and stabilising agents respectively.

The resulting mixture was heated on a hot plate at a controlled temperature of 70–90 °C with continuous stirring until the starch underwent gelatinisation, producing a thick, homogeneous gel. While still hot, the gel was poured onto a clean, flat casting tray and spread

evenly with a spatula to achieve a uniform thickness. The cast sheet was dried either in an oven at 50–60 °C for 1–2 hours or under sunlight for 1–2 days, after which it was carefully peeled off the tray and stored in a dry environment prior to testing.

C. Experimental Evaluation

The fabricated mulch sheet was subjected to five performance tests, each repeated over two to three trials to ensure repeatability of the recorded values.

1) Water Permeability Test

A fixed volume of water (100 mL) was poured onto a sample fixed over a perforated support, and the volume passing through the sheet within a measured time interval was recorded. This test indicates whether the sheet permits sufficient water infiltration to the soil while limiting excessive loss.

2) Moisture Retention Test

Two identical soil-filled containers were each saturated with 200 mL of water; one was covered with the mulch sheet while the other was left uncovered as a control. Both were placed under identical environmental conditions, and the weight loss of each container — indicating evaporative moisture loss — was recorded over a 24–48 hour period.

3) Biodegradability Test

Weighed sheet samples were buried at a depth of 5–10 cm in moist soil and exhumed at fixed intervals (0, 15, 30, and 45 days) to record residual weight, visible fragmentation, and overall physical breakdown, giving a quantitative measure of the decomposition rate.

4) Thickness Test

Sheet thickness was measured at five distinct points using a micrometer screw gauge, and the average value was computed to assess the uniformity of the casting process.

5) Tensile Strength Test

Standard strips (10 cm × 2 cm) cut from the sheet were clamped at both ends and loaded incrementally until failure. The load at break, together with the cross-sectional area of the strip, was used to compute the tensile strength of the material.

IV. RESULTS

A. Water Permeability

Across three trials, the mulch sheet allowed approximately 65–68% of the applied water to pass through within 120–125 seconds, with the remainder retained at the surface (Table II). This moderate, consistent

permeability indicates that the sheet permits adequate water infiltration to the soil without allowing excessive, uncontrolled flow-through.

TABLE II. WATER PERMEABILITY TEST RESULTS

Trial	Water Applied (mL)	Time (s)	Water Passed (%)
1	100	120	65
2	100	125	68
3	100	122	66

B. Moisture Retention

Over the observation period, the uncovered (control) soil lost 110 mL of its initial 200 mL of water, retaining only 45%, whereas the mulch-covered soil lost just 50 mL, retaining 75% (Table III). The mulch sheet thus reduced evaporative moisture loss by 30 percentage points relative to bare soil.

TABLE III. MOISTURE RETENTION TEST RESULTS

Soil Condition	Initial Water (mL)	Final Water (mL)	Retained (%)
Uncovered (control)	200	90	45
Mulch-covered	200	150	75

C. Biodegradability

The sheet showed no measurable weight loss at day 0, 16% degradation by day 15, 44% by day 30, and 76% by day 45 (Table IV), confirming a steady, accelerating decomposition profile under moist soil conditions.

TABLE IV. BIODEGRADABILITY TEST RESULTS

Duration (days)	Residual Weight (g)	Degradation (%)
0	50	0
15	42	16
30	28	44
45	12	76

D. Thickness

Thickness measured at five points ranged narrowly from 2.4 to 2.7 mm, giving an average of 2.56 mm (Table V), indicating reasonably uniform sheet formation during casting.

TABLE V. THICKNESS TEST RESULTS

Observation Point	Thickness (mm)
1	2.5
2	2.7
3	2.6
4	2.4

5	2.6
Average	2.56

E. Tensile Strength

The load at break ranged from 18 to 20 N across three trials, corresponding to a tensile strength of 0.90–1.00 N/mm² and an average of 0.95 N/mm² (Table VI).

TABLE VI. TENSILE STRENGTH TEST RESULTS

Trial	Load at Break (N)	Tensile Strength (N/mm ²)
1	18	0.90
2	20	1.00
3	19	0.95
Average	—	0.95

V. DISCUSSION

The combined results indicate that the banana-peel/corn-flour mulch sheet achieves a practical balance between water regulation and moisture conservation. Its moderate permeability (65–68% pass-through, Table II) allows adequate water to reach the underlying soil, while the 75% moisture retention recorded for mulch-covered soil — against only 45% for bare soil (Table III) — demonstrates a substantial reduction in evaporative loss, consistent with the moisture-conservation behaviour reported for biodegradable mulch films elsewhere [6], [13]. In practical terms, this translates into reduced irrigation frequency and more consistent soil-moisture availability for plant growth.

The biodegradability data (Table IV) show that decomposition accelerates after the first fortnight, reaching 76% degradation by day 45 — a rate broadly consistent with the degradation behaviour reported for starch-rich bioplastics [11] and fast enough to avoid the long-term soil accumulation associated with polyethylene mulch [9], [25]. As the sheet breaks down, it returns organic carbon, potassium, and other nutrients to the soil, providing a fertility benefit that conventional plastic mulch cannot offer.

The average thickness of 2.56 mm (Table V) was reasonably uniform across the sampling points, the small variation (2.4–2.7 mm) being attributable to manual spreading during casting; such uniformity is important because an overly thin sheet is prone to tearing, while an overly thick sheet would reduce permeability and delay biodegradation. The average tensile strength of 0.95 N/mm² (Table VI) indicates that the sheet can withstand routine handling and field installation without immediate

failure — an effect attributable to the combined reinforcing action of corn flour and the plasticising effect of glycerin [4], [10].

Relative to conventional polyethylene mulch, the developed sheet offers comparable functional performance in moisture conservation and an inherent capacity for weed suppression through physical blocking of light transmission, while eliminating the need for post-season removal and disposal — a major cost and labour saving for farmers. Its principal limitation is a lower tensile strength relative to plastic film, suggesting that it is best suited to short-duration cropping cycles rather than repeated multi-season use. This limitation could be addressed through natural-fibre reinforcement [10], an optimised starch-to-plasticiser ratio, or a modest increase in thickness for crops requiring a longer mulching duration — directions identified for future investigation.

VI. CONCLUSION

This study successfully developed and evaluated a biodegradable mulch sheet fabricated from banana peel waste, reinforced with corn flour, plasticised with glycerin, and stabilised with vinegar. The developed sheet exhibited a moderate, agriculturally favourable water permeability (65–68%), substantially improved moisture retention relative to uncovered soil (75% versus 45%), a fairly uniform average thickness of 2.56 mm, an adequate average tensile strength of 0.95 N/mm² for field handling, and complete biodegradation of over three-quarters of its mass within 45 days — returning nutrients such as potassium and organic carbon to the soil during decomposition. These findings confirm that banana-peel-based mulch sheets are a cost-effective, eco-friendly, and technically viable substitute for conventional plastic mulch, simultaneously addressing agricultural waste management and the environmental burden of plastic residues.

Future Scope: Future work may focus on enhancing the mechanical strength of the sheet through natural-fibre reinforcement (e.g., coconut fibre), validating performance under real field conditions across full crop cycles, optimising the starch-to-additive ratio to tune the biodegradation rate to specific crop durations, extending the approach to other starch-rich agro-wastes such as rice husk or sugarcane bagasse, and conducting a cost–economic feasibility study to support large-scale adoption by farmers.

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