

Bioplastic from Banana Peels: An Eco-Friendly Alternative to Conventional Plastic

19 **Abstract**

20 Due to their non-biodegradable nature and long degradation time, conventional plastics are a major source
21 of environmental pollution today. In this study, the production of biodegradable plastic from banana peel
22 waste, is explored as an abundant and renewable biomass resource. Chemical and natural based methods
23 were employed to synthesize bioplastic films using banana peel mash and additives like glycerol as
24 plasticizer. Physical properties of the prepared films were characterized by water absorption, swelling, and
25 solubility tests in multiple solvents. Chemical-based bioplastic was found to be more fragile, while natural-
26 based bioplastic exhibited higher water absorption and structural integrity was maintained. However, both
27 the films were insoluble in water and other solvents used, which confirmed their potential durability and
28 biodegradability. Optimization of the methods employed needs to be carried out along with finding new natural
29 materials for the strengthening of the films. This research, however, concludes that the bioplastic films made may
30 offer a sustainable and low-cost alternative to conventional petrochemical plastics. These films have possible
31 applications in packaging and carry bag manufacturing industries as the research findings support bioplastic
32 research conducted globally to mitigate the plastic pollution problem.

33 **Keywords:** *Bioplastic, Banana peel, Biodegradable, Plasticizer, Environmental pollution*

34

35 **Introduction**

36 Plastic pollution is a serious global environmental crisis that requires urgent attention on development of
37 alternatives to conventional petrochemical-based plastics, which are known to persist in every ecosystem
38 for centuries and their degradation leads to release of toxic substances (Geyer et al., 2017; Andrady, 2011).
39 Renewable resources such as agriculture waste, rich in starch, are used to develop bioplastics, offer an eco-

40 friendly solution owing to their enhanced biodegradability and lower to none environmental toxicity (Subbaraju
41 et al., 2025). Banana peels constitute a significant amount of agro-wastes that are abundant. They contain
42 substantial quantity of starch and other biopolymers that are suitable for bioplastic production (Lakkimsetty
43 et al., 2025). Despite their potential, banana peel-based bioplastics are largely understudied and very less
44 explored sustainable materials (Subbaraju et al., 2025).

45 A valuable agro-waste material, banana peels, are known to be rich in useful components like starch,
46 cellulose, and hemicellulose, this enables them to be a potentially effective resource for bioplastic production
47 (Khan et al., 2022). Amylose and amylopectin, primarily makes up a robust matrix that gives bioplastics the
48 desirable physical and mechanical properties. Banana peel starch when mixed with natural plasticizers such
49 as glycerol or additives like carboxymethyl cellulose is reported to improve the flexibility, tensile strength, and
50 elongation of the resulting films, making them suitable for packaging and disposable applications (Verma et
51 al., 2025). Recent studies have demonstrated that higher starch content enhanced solubility, water vapor
52 permeability, swelling, and biodegradability, with improved cohesive microstructure and film performance, as
53 revealed via FTIR and SEM analyses (Wali et al., 2023).

54 Satisfactory tensile strength (up to 2 MPa) and tear resistance, is reported after mechanical testing of banana
55 peel bioplastics, thus validating their potential for daily use (Vinodh et al., 2021). Rapid biodegradation in
56 soil and compost conditions, can be seen which is far faster than synthetic plastics—a key environmental
57 advantage (Sebastian et al., 2025). Banan peels have inherent properties such as antimicrobial properties,
58 which are transferred to the bioplastics developed from them, offering added value for applications like food
59 packaging where hygiene is critical (Kirubagari Aneeshia et al., 2022). Along with economic and ecological
60 benefits, recently improved antioxidant and UV resistance performance are also highlighted, making banana
61 peel-derived bioplastics promising alternatives that are beneficial for the environment (Embrapa, 2024).

62 When combined with plasticizers such as glycerol and natural additives, banan peel bioplastics exhibits
63 desirable physical, chemical, and mechanical properties (Talukdar et al., 2025; Dimassi et al., 2022). These
64 bioplastics are potential candidates for short-term use products which can be disposed easily and these
65 applications contributes to circular economy initiatives aimed at sustainable material development from
66 renewable or waste sources (Marichelvam et al., 2025). There is very limited comparative knowledge on
67 chemical versus natural processing methods for banana peel-based bioplastic formulations. Their water
68 absorption, swelling, and solubility behavior in environmentally relevant solvents is also not clearly
69 understood.

70 This study aims to develop bioplastics from banana peel through both chemical and natural processing
71 methods. Followed by the characterization of their physical and chemical properties including water
72 absorption, swelling, and solubility, and evaluate their prospects as biodegradable alternatives to
73 conventional plastics. This work positively contributes to advancing sustainability science by valorizing
74 agricultural waste and exploring bioplastics with desired functional properties.

75

76 **Materials and Methods**

77 **Materials**

- 78 - Banana peels sourced from local fruit juice vendor and household waste, thoroughly washed
- 79 and cut into small pieces.
- 80 - Chemicals: Hydrochloric acid (HCl), Sodium hydroxide (NaOH), glycerol, vinegar, aloe vera,
- 81 cinnamon, and thyme.

82 **Methodology**

83 **Preparation of Banana Peel Paste**

84 Banana peels were collected from house and local fruit juice vendors. These peels were thoroughly washed
85 with tap water and cut into small pieces of approximately 1 cm by 1 cm, after which they were dipped in Sodium
86 meta bisulphite for around 40 minutes. The peels were strained out and washed again with distilled water
87 and kept for boiling in fresh distilled water for 60 minutes. The water was thrown and peels were left to air
88 dry for for an hour on filter paper. The dried peels were ground to a uniform paste using a blender.

89 **Bioplastic Synthesis**

90 **Chemical-Based Bioplastic**

91 25 g of the banana paste prepared was mixed with 3 mL of HCl, 2 mL of glycerol (plasticizer), and 3 mL of
92 NaOH to adjust pH. After mixing thoroughly the mixture was stirred continuously for 5 minutes and spread
93 uniformly on parchment paper. The paper was then placed in oven for drying at 100°C - 120 °C.

94 **Natural-Based Bioplastic**

95 30 g of the banana paste was boiled for 5 minutes and then filtered to remove excess water. Natural
96 ingredients like vinegar (12 mL), aloe vera (2.5 g), cinnamon (0.75 g), and thyme (0.5 g) were added to the
97 paste and mixed thoroughly. It was then spread uniformly on parchment paper and oven-dried at 100°C -
98 120 °C .

99 **Characterization Tests**

100 The dried bioplastic films (chemical and natural based) were then subjected to multiple characterization tests
101 for understanding it's phycochemical properties and its application suitability. Bioplastic samples were cut
102 into 2 cm x 2 cm and used for following tests.

103 **Water Absorption Test**

104 Bioplastic samples were immersed in distilled water for 24 hours at room temperature and weight change
105 calculated as percentage.

106 **Swelling Test**

107 Bioplastic samples were immersed in distilled water, chloroform, and methanol separately for 2 hours and
108 the weight differences were recorded.

109 Solubility Test

110 Bioplastic samples were tested in ammonia, acetic acid, acetone, sulfuric acid, ethyl alcohol, and distilled
111 water to evaluate solubility patterns.

112 Shelf life of the prepared bioplastic

113 Bioplastic samples were carefully placed in garden soil collected from the college garden. The samples were
114 labeled properly and examined on 7th, 14th, 21st, 28th day. Few samples were kept on the laboratory counter
115 exposed to natural light and air. After a month they were transferred to a ziplock bag and stored.

116 On the 14th day of observation, fungal action was observed on bioplastic prepared based on the chemical
117 based. But in sample incorporated with natural based, fungal action was observed only on the 10th day. The
118 presence of chemicals could enhance the shelf-life of the bioplastics.

119 Results

120 Apart from making sheets of bioplastics different moulds were used for understanding their applicability. The
121 sheets were separated from the parchment paper effortlessly and were intact. The peel mixture held the
122 shape of the mould (bowl and plate) after drying as seen in figure 1.



123

124 **Figure 1: Bioplastic films and moulds produced**

125 Water Absorption

126 This test is performed to check whether the bioplastic produced maintains its structural integrity after exposed
127 to water. As mentioned in table 1, natural-based bioplastic absorbed significantly more water (146.1%) than
128 chemical-based (73.3%), indicating higher hydrophilicity but maintained integrity in aqueous media. Though
129 the water absorption was high in both the films, the structural integrity was maintained.

130 **Table 1: Water Absorption test**

Sample type	Initial Weight (g)	Final Weight (g)	Water Absorption (%)

Chemical-based Bioplastic	0.30	0.52	73.3
Natural-based Bioplastic	0.13	0.32	146.1

131

132 **Swelling Behavior**

133 Different aqueous medium were used to understand the behaviour of the bioplastic films when in contact. Both
 134 bioplastics swelled most in distilled water and least in methanol, indicating solvent-dependent protuberance
 135 (Table 2). Chemical-based bioplastic showed slightly lower swelling than natural-based, indicating higher
 136 structural stability.



137

138 **Figure 2: Swelling test in different aqueous medium**

139 **Table 2: Swelling test**

Sample Type	Distilled Water (%)	Chloroform (%)	Methanol (%)
Chemical-Based	120.5 ± 1.8	93.2 ± 2.1	58.7 ± 1.5
Natural-Based	135.7 ± 2.0	102.5 ± 1.9	68.3 ± 2.2

140

141 **Solubility**

142 Both bioplastics were subjected to multiple solvent meidum like water and inorganic solvents. The films were
 143 insoluble in water and most organic solvents, but partially soluble only in ammonia, and completely soluble
 144 in sulfuric acid, indicating good chemical resistance which is favorable for applications as packaging materials
 145 (Table 3).



146

147 **Figure3: Solubility test in different solvent**

148 **Table 3: Solubility test**

Solvent	Chemical-Based Bioplastic	Natural-Based Bioplastic
Ammonia	Partial Solubility	Partial Solubility
Acetic Acid	Insoluble	Insoluble
Acetone	Insoluble	Insoluble
Sulfuric Acid	Complete Solubility	Complete Solubility
Ethyl Alcohol	Insoluble	Insoluble
Distilled Water	Insoluble	Insoluble

149

150 **Shelf life**

151 The biodegradation of the films were studied by soil burial method. The natural samples burried in garden
 152 soil were degraded completely around 13th day, while the chemical based were degraded around 20th day.
 153 Both natural-based and chemical-based bioplastic samples which were exposed to natural light and air, after
 154 3-4 months the natural-based ones started to loose its integrity after a month, while chemical-based retained
 155 its structure. The films stored in the zip lock bags showed no changes. No fungal growth was observed on
 156 films stored in both conditions, confirming the antimicrobial property imparted by the additives.



157

158 **Figure 4: Natural-based and Chemical-based**
159 **bioplastic samples stored in zip lock bag**

Figure 5: Natural-based bioplastic samples
exposed to natural air and light

160 **Discussion**

161 Bioplastics are the need of the hour and banana peels possess the potential for being a suitable candidate
162 as a raw material that can be used for bioplastic production. In this study, both chemical and natural methods
163 were employed to produce bioplastics. Chemical and natural ingredients were used as plasticizers to make
164 the films and a comparative evaluation of the physical and chemical properties of the both films was performed.
165 Various tests (such as. Solubility test, swelling test, water absorption test and biodegradation tests) were
166 carried out. The results positively confirmed that banana peels can be effectively used to produce bioplastics
167 with suitable mechanical and physicochemical properties. This established their functional suitability in daily
168 applications. Both chemical and natural formulations can be used for producing bioplastic of which chemical-
169 based films showed more structural integrity than the natural-based ones. Higher water absorption by natural-
170 based bioplastics suggests potential use in applications requiring flexibility and moisture interaction, whereas
171 chemical-based bioplastics offer more rigidity (Subbaraju et al. 2025). This also highlights the need to
172 optimize the natural-based formulation for altering the hydrophilicity so that it can have broader applications.
173 Testing solubility, shelf life, biodegradation, swelling, and water absorption is vital in evaluating bioplastics
174 because these tests collectively determine their physical stability, durability, environmental impact, and
175 suitability for practical applications. Solubility tests reveal how bioplastics interact with various solvents, which
176 affects how they can be processed, used, or disposed of safely (IJNRD, 2023). Shelf life assessments
177 measure how these materials maintain integrity when exposed to environmental stresses like temperature
178 and humidity, ensuring their functional longevity (Ghizdareanu et al., 2023). Biodegradation testing evaluates
179 the rate and extent to which bioplastics decompose under natural or simulated conditions, confirming their
180 eco-friendliness and potential to reduce plastic pollution (Tosin et al., 2012; Folino et al., 2023). Swelling and
181 water absorption tests provide insight into how bioplastics absorb moisture or liquids and change physically,
182 impacting mechanical strength and suitability in humid or wet environments (IJNRD, 2023; Santana et al.,

183 2017). Together, these tests guide the optimization of bioplastic formulations to ensure they meet required
184 standards of performance, safety, and environmental sustainability. The results very much aligns with many
185 of the documented reports that highlighted the role of glycerol as a plasticizer and suitability of banana peel
186 waste for bioplastic production (Noor R, et al. and Sofiah S, et al.). Natural additives like aloe vera and
187 spices has shown good potential to enhance biodegradation and also imparts antimicrobial properties to the
188 films, which will definitely be beneficial for packaging applications (Subbaraju et al. 2025).

189 The study offers cost-effective solutions to plastic pollution which also can help in dealing with agro-waste
190 efficiently. Further advancements and scale up may result in an optimized bioplastic formulation ready for
191 application.

192 **Conclusion**

193 Banana peel-derived bioplastics, both chemical and natural-based, has a great potential as an eco-friendly
194 packaging material alternatives. Both the bioplastic films produced exhibited beneficial water absorption,
195 swelling, and solvent resistance critical for practical use. Natural-based bioplastics offer enhanced flexibility,
196 while chemical-based variants provide improved mechanical strength. Recent advances suggest promising
197 future prospects for bioplastic production from banana peels, leveraging their abundant starch and
198 lignocellulosic fibers. Banana peel-derived bioplastics are garnering attention as sustainable, cost-effective
199 alternatives to petroleum-based plastics, addressing plastic pollution and waste management challenges
200 globally (Subbaraju et al., 2025). The fibrous microstructure and polysaccharide content provide excellent
201 mechanical strength and flexibility when combined with natural plasticizers like glycerol (Lakkimsetty et al.,
202 2025). Enhanced biodegradability and environmental compatibility position these materials as ideal for
203 disposable packaging, agricultural films, and single-use items (Talukdar et al., 2025; Kumari et al., 2025).

204 Innovative formulations incorporating chitosan, fish scales, and other biopolymers have improved tensile
205 strength, flexibility, and functional properties such as antimicrobial and UV-protective effects, expanding
206 application scopes (Lakkimsetty et al., 2025). The implementation of design optimization tools enables
207 tailoring physical properties for industrial requirements, supporting circular economy models that valorize
208 agricultural waste (Kumari et al., 2025; Marichelvam et al., 2025).

209 Challenges remain in scaling production, cost optimization, and ensuring consistent performance versus
210 conventional plastics. However, ongoing research into blending, cross-linking, and additive incorporation
211 aims to overcome these barriers (Subbaraju et al., 2025). As regulatory frameworks and consumer demand
212 for sustainable packaging grow, banana peel bioplastics are poised to play a significant role in greener
213 materials markets, contributing to waste reduction and climate impact mitigation.

214 This work contributes in valorizing agro-industrial residues into biodegradable materials by using effective
215 plastic waste reduction strategies.

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