

# Development of Sustainable Bioplastic Film from Banana Peel and Corn Starch

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## ABSTRACT

This study focuses on developing a biodegradable bioplastic film using banana peel and corn starch as primary materials. The banana peel provides a rich source of cellulose, while corn starch contributes to the film's strength and flexibility. The materials were blended with natural plasticizers, heated, and moulded into films. The bioplastic film was characterized by analytical techniques such as FTIR, TGA-DSC and Load test. Biofilms are environmentally friendly as they can naturally filter pollutants, promote nutrient cycling, and support sustainable waste treatment processes in ecosystems. This approach not only reduces waste but also promotes the use of agricultural by-products, contributing to sustainable resource management and environmental conservation.

**KEYWORDS:** Sustainable Bioplastic Film, Banana peel, Corn Starch, agricultural by-products.

## 1. INTRODUCTION:

Plastics play an integral role in modern society, and by 2010, global production was estimated at about 265 million tonnes, of which approximately 57 million tonnes originated from Europe [1]. Polymer films are widely preferred for packaging applications because of their adaptability, affordability, and barrier properties. Commonly used plastic polymers in the packaging sector include low-density polyethylene (LDPE), high-density polyethylene (HDPE), and polyvinyl chloride (PVC). Despite their usefulness, these synthetic plastics are not biodegradable, meaning that natural microorganisms are unable to break them down once they enter the environment [2]. Consequently, they accumulate over time and contribute significantly to solid waste pollution. The exploration of eco-friendly alternatives such as bioplastics can be traced back to the early 20<sup>th</sup> century, when Henry Ford experimented with plant-derived oils, including corn and soybean, for the fabrication of automobile components [3].

Today, the bioplastics industry is gaining momentum, driven by the global demand for sustainable plastic alternatives. Naturally derived macromolecules, including starch, sugars, disaccharides and fatty acids, are being explored as primary materials for bioplastic production. Starch, in particular, is a prominent biopolymer used in this field due to its wide availability, cost-effectiveness, renewable nature and biodegradability. Structurally, starch is composed of two glucose-based polymers, amylopectin and amylose which together form its granular structure. Starch, when blended with plasticizers and

processed under heat and shear, can be transformed into a thermoplastic material [4]. However, films made solely from native starch tend to be brittle and absorb water easily. To overcome these limitations, additional natural polymers are often incorporated to enhance the functional properties of starch-based bioplastic films [5].

Banana peels represent a major source of starch-rich agricultural waste, and their disposal remains a pressing challenge, particularly in developing nations. In Malaysia, for instance, industries producing banana-based products such as cakes, chips, and fritters primarily utilize the fruit pulp, while the peels are commonly discarded. The accumulation of this moist organic waste can have detrimental environmental effects and may lead to health issues, including respiratory conditions [6]. Notably, banana peels are rich in starch, containing approximately 18.5% starch content [7]. As the peel matures, its glucose concentration rises. Over-ripened peels convert most of their starch into glucose, whereas under-ripened peels, though starch-rich are often too firm for easy processing [8]. This makes banana peels a promising candidate for bioplastic production. Similarly, corn is another widely recognized starch source and a major part of the human diet. Despite its significance, some parts of the corn plant are still treated as waste. Extensive research has been carried out on the potential of corn starch for bioplastic applications. In this study, corn starch is incorporated as a secondary biopolymer alongside banana peel starch, which serves as the primary material. While earlier research has mainly explored the use of banana peel alone in starch-based film production. This investigation proposes a new formulation by blending starches from two different natural sources. While cellulose has been widely employed as a reinforcing filler in starch-based bioplastics [9]. The present study emphasizes the use of a dual-starch strategy.

The objectives of this research include analyzing the tensile strength of banana peel and corn starch-based films, determining their water absorption capacity, and characterizing them based on functional groups and thermal behavior. Despite being one of the most consumed fruits worldwide, bananas generate large volumes of peel waste, typically discarded in municipal landfills thereby worsening environmental pollution [10]. The study aims to demonstrate that bioplastics derived from this combination of agricultural waste materials can offer a viable alternative to conventional plastics. Driven by strong governmental support for green policies, increased environmental awareness, and the threats posed by emissions from incineration, research has shifted towards sustainable materials [11]. As a result, public interest in products made from renewable resources has grown significantly.

## **2. MATERIALS AND METHODS**

### **Materials**

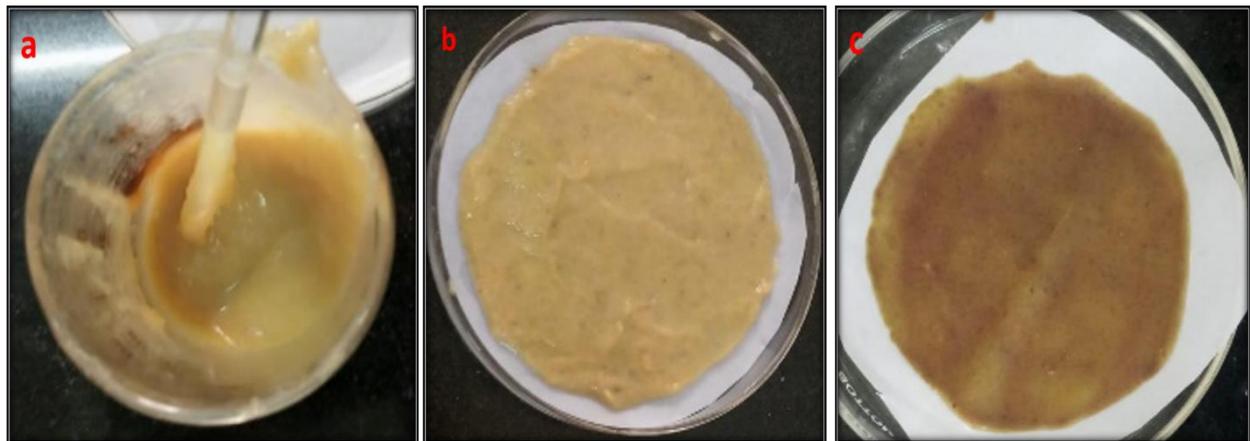
Banana was purchased from the local market and corn starch; vinegar and honey was purchased from grocery shop. The chemicals used in this work consist of hydrochloric acid, (HCl, Molychem, AR, 35.8 %), sodium hydroxide (NaOH, Molychem, AR 98%). Other reagents and chemicals used were of high purity. Double distilled water was used for the preparation of sample solutions throughout experiment.

### Preparation of the Banana peels

Remove the peels from banana by using a knife and 100 g of banana peels were dipped into 45 mL vinegar solution and the peels were then placed into a beaker containing 265 mL water and boiled for 20-25 min. The water was reduced and the peels were left to dry at room temperature.

### Preparation of Bioplastic film

To prepare the bioplastic film, banana peels were blended into a smooth puree using a blender. From this puree, 25 g were transferred into a 50 mL beaker containing 3 mL of 0.5 M hydrochloric acid (HCl), and the mixture was stirred thoroughly to get homogenous solution. Following this, 2 mL of honey was incorporated and stirred again. Then, 3 mL of a 1% corn starch solution was added as a co-biopolymer. Afterward, 3 mL of 0.5 M sodium hydroxide (NaOH) was added and mixed well. (**Fig. 1a**), The resulting mixture was evenly spread on a sheet of butter paper (**Fig. 1b**), which was then placed in an oven set to 110 °C for 50 min. until fully dried. Once dry, the film was removed from the oven, allowed to cool it to room temp. (**Fig. 1c**), and carefully peeled off from the butter paper.



**Fig.1.** Making bioplastic (a) Addition of solutions (b) Spreading the mixture (c) Dry bioplastic film

## 3. RESULT AND DISCUSSION

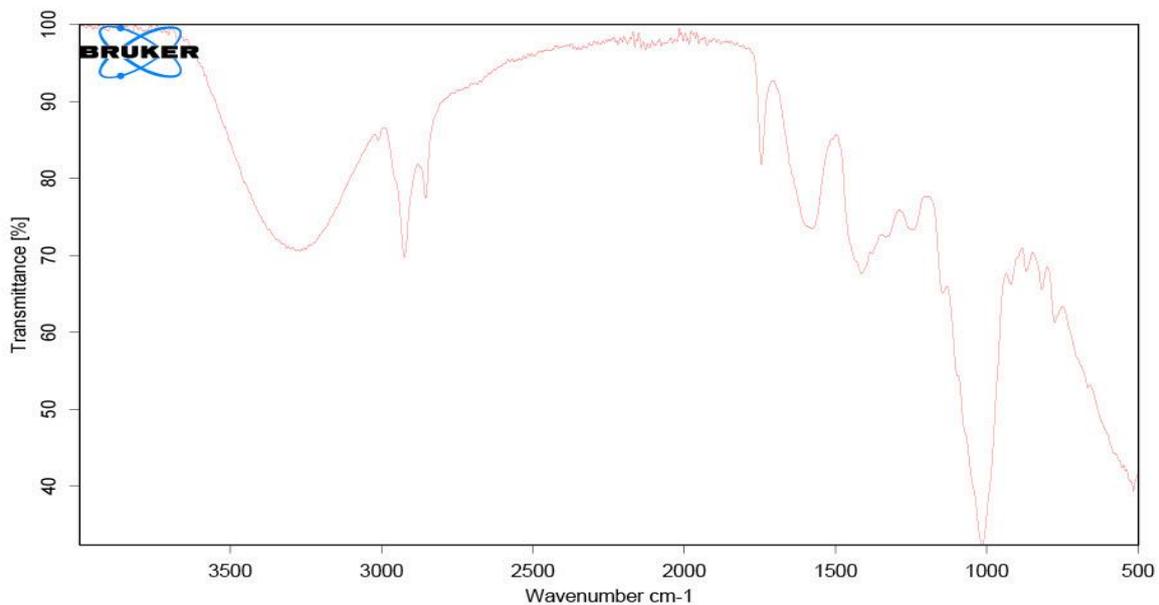
### Load Test (Tensile Strength)

This assessment was conducted to evaluate the mechanical behavior of the bioplastic film when subjected to tensile loading. Tensile strength testing determines the materials ability to withstand pulling forces and provides insight into its suitability for practical applications such as packaging. In the present study, the bioplastic film prepared from banana peel and corn starch was subjected to a tensile load until failure occurred. The results indicated that the maximum tensile strength recorded was 781.64 psi (12.54%), while the minimum tensile strength was 208.67 psi (4.86%). The average tensile strength of the film was found to be 411.45 psi (8.98%). When converted into SI units, the average tensile strength corresponds to  $2.84 \times 10^6$  N/m<sup>2</sup> (2.84 MPa). These values demonstrate that the bioplastic film possesses moderate mechanical strength, which is adequate for lightweight packaging applications.

Tensile strength is a critical parameter for evaluating the durability and structural integrity of bioplastic materials. The observed mechanical performance suggests that the film can withstand reasonable tensile stresses; however, further improvement in strength and flexibility may be achieved through the incorporation of suitable plasticizers or reinforcing agents. Such modifications could enhance the applicability of the bioplastic film for broader industrial and commercial uses.

### Fourier Transform Infrared Spectroscopy (FTIR)

FT-IR spectroscopy is a powerful technique used to analyse the chemical composition of materials and interpret their spectral characteristics. By comparing the strong absorption peaks in the sample's spectrum to known reference values, the functional groups present in the bioplastic can be identified (**Fig. 2**). Bands found within the  $1000\text{-}1300\text{ cm}^{-1}$  (C–O Stretching) range are typically associated with ester, ether, or alcohol functional groups. Absorption in the  $1500\text{-}1600\text{ cm}^{-1}$  region indicates the presence of aromatic structures within the sample. Peaks appearing between  $2800\text{ and }3000\text{ cm}^{-1}$  suggest the existence of alkyl groups in the bioplastic. A broad peak observed in the  $3200\text{-}3550\text{ cm}^{-1}$  range points to hydroxyl groups, which contribute to the hydrophilic nature of the material. These spectral features reflect the chemical structure of the bioplastic film, indicating the presence of alcohols, aromatic compounds, and hydrocarbon groups.



**Fig. 2.** FTIR Transmission spectra of banana peel/corn starch bioplastic film

### Differential Scanning Calorimetric (DSC)

Differential Scanning Calorimetry (DSC) is a widely used thermal analysis technique that measures the heat flow associated with phase transitions in materials as a function of temp and time. It provides valuable information about the thermal behavior and structural characteristics of polymeric substances.

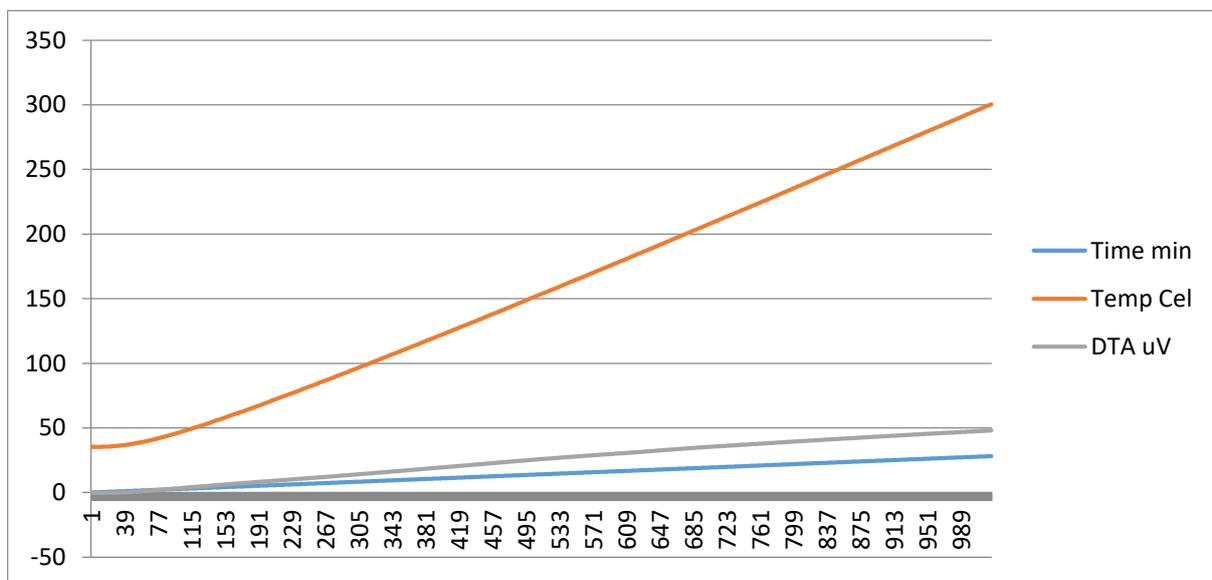
The DSC curve for the banana peel/corn starch bioplastic film (**Fig. 3**) illustrates the relationship between temperature, heat flow, and time. The temperature steadily increases throughout the test, reaching

approximately 320 °C, while the differential thermal analysis (DTA) response and time progression was also recorded.

The initial segment of the curve, up to around 100 °C, reflects the endothermic event related to the evaporation of moisture and any loosely bound water within the film matrix. This is common in bioplastics containing starch and other hydrophilic substances derived from natural sources. As the temperature continues to rise, the graph suggests a gradual increase in heat flow, which may indicate glass transition or softening behavior, particularly within the 100 °C to 180 °C range. In this region, polymer chains begin to exhibit increased molecular mobility without undergoing decomposition.

Further along the curve, any noticeable deviation or peak (typically above 200°C) would signify melting or degradation events. For this sample, the gradual increase in the DTA signal suggests that the biopolymer system maintains relative thermal uniformity without sharp phase transitions, implying good thermal homogeneity and stable interpolymeric interactions between banana peel constituents and corn starch.

Overall, the DSC data demonstrates that the bioplastic possesses a moderate thermal resistance and predictable heat absorption characteristics, making it suitable for applications requiring stable performance under controlled thermal conditions.



**Fig. 3.** Differential Scanning Calorimetry (DSC) of banana peel/corn starch bioplastic film

### Thermogravimetric Analysis (TGA)

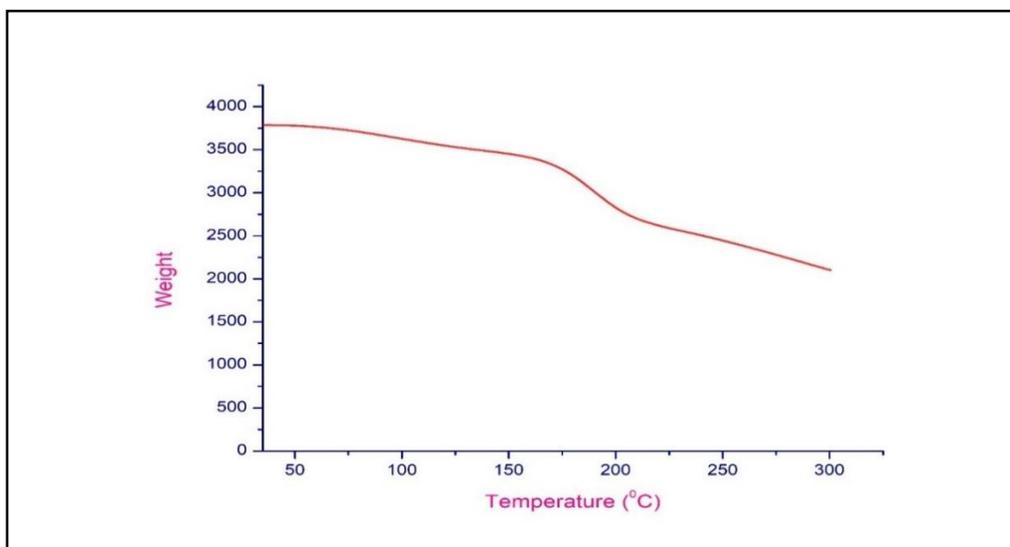
Thermogravimetric analysis (TGA) is a technique used to assess the thermal stability and composition of polymer-based materials by measuring weight loss as a function of increasing temperature. The TGA curve obtained for the banana peel/corn starch bioplastic film (**Fig. 4**) indicates a multi-stage thermal degradation profile, which is typical for biopolymeric materials.

The initial weight loss observed below approximately 120 °C is attributed to the evaporation of residual moisture and low molecular weight volatile compounds. This is a common behaviour for natural polymer matrices, as they tend to retain some water due to their hydrophilic nature.

The second stage of degradation, occurring between roughly 150 °C and 250 °C, corresponds to the breakdown of hemicellulose and other less thermally stable organic constituents, including plasticizers and certain starch components. This stage is characterized by a noticeable decline in weight, reflecting the release of volatile degradation products.

The final stage, extending from around 250 °C to 350 °C, involves the decomposition of more thermally stable components such as cellulose and possibly lignin residues from the banana peel. This phase typically results in a slower but continuous weight loss, signifying the degradation of the biopolymer backbone and the formation of a carbonaceous residue.

Overall, the TGA profile demonstrates that the banana peel/corn starch bioplastic exhibits moderate thermal stability, making it potentially suitable for applications that do not involve exposure to high temperatures. The distinct degradation stages also confirm the presence of various organic fractions within the bioplastic composite.



**Fig.4.** Thermogravimetric analysis (TGA) of banana peel/corn starch bioplastic film

#### 4. CONCLUSION

This study demonstrates that bioplastic films can be successfully fabricated using banana peel and corn starch, both of which are natural, biodegradable, and renewable materials. The developed films exhibited satisfactory mechanical strength and flexibility, along with reasonable thermal stability. FTIR analysis confirmed the presence of characteristic functional groups associated with biopolymer interactions, while DSC and TGA results indicated that the bioplastic could withstand moderate temperatures without rapid thermal degradation.

The utilization of banana peel, an abundant agricultural waste, in combination with corn starch highlights an effective strategy for converting waste biomass into value-added, environmentally friendly materials. This approach not only contributes to the reduction of plastic pollution but also promotes sustainable material development. Future studies may focus on enhancing the durability and water resistance of the bioplastic films, thereby broadening their potential applications in packaging and other industrial sectors.

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