# A Review on Biodegradable Films from Banana Peel


## ABSTRACT

The increasing environmental issues associated with plastic waste have sparked a heightened interest in the creation of biodegradable alternatives derived from renewable resources. One notable option is biodegradable film made from banana peels, which presents an environmentally friendly and sustainable solution. This review examines the viability of utilizing banana peels as a raw material for the production of biodegradable films. It investigates the chemical makeup of banana peels, emphasizing the presence of starch, cellulose, and pectin, which are essential for film formation. The review further addresses various processing techniques, including starch extraction, plasticization, and cross-linking, that improve the mechanical properties and biodegradability of the films. Moreover, it analyzes the environmental implications, potential applications in food packaging, and the challenges related to scalability and cost-effectiveness. The findings indicate that biodegradable films derived from banana peels represent a promising substitute for petroleum-based plastics; however, additional research is necessary to enhance their mechanical strength and commercial feasibility. The review concludes by advocating for ongoing investigation into natural waste resources for the development of sustainable materials.



**Keywords:** Biodegradable Film; Banana Peel; Food waste; Bio film; Packaging.


## 1. INTRODUCTION

In recent years, the growing environmental issues associated with the overuse of synthetic plastics have prompted significant research into sustainable alternatives. Biodegradable films have emerged as viable substitutes due to their natural degradation capabilities, which help mitigate pollution. Among the various organic materials being investigated, banana peels, a prevalent form of agricultural waste, have attracted considerable interest. Films derived from banana peels offer an eco-friendly solution by transforming organic waste into useful products, thereby reducing environmental impact while providing a range of mechanical and physical properties suitable for packaging and other industrial uses. The global dependence on plastic has led to a severe waste management crisis, particularly as synthetic plastics are non-biodegradable and can remain in the environment for centuries. It is estimated that approximately 8 million tons of plastic waste enter the oceans each year, with projections indicating that plastic pollution could quadruple by 2050 unless sustainable alternatives are implemented [17, 33, 42, 15, 55].

The use of plastic packaging presents numerous detrimental effects on both the environment and public health. To begin with, the breakdown of plastic waste generates microplastics, which infiltrate ecosystems and threaten marine organisms as well as human health by entering the food chain [71]. Furthermore, plastic packaging is a major contributor to greenhouse gas emissions throughout its entire life cycle, especially during the production and disposal phases [69]. Additionally, plastic packaging often contains toxic substances that can leach into food, including endocrine disruptors and carcinogenic compounds, thereby posing significant health risks [70]. Finally, despite ongoing recycling initiatives, the accumulation of plastic packaging waste continues due to inadequate recycling facilities and improper disposal methods, leading to enduring pollution [68].

Biodegradable plastics made from organic materials such as banana peels are emerging as a promising response to this pressing environmental challenge [25, 48]. Banana peels are a rich source of natural biopolymers, including starch, cellulose, and pectin, making them particularly suitable for the creation of biodegradable films. These biopolymers can be processed into films that exhibit desirable mechanical and thermal properties. Research indicates that cellulose extracted from banana peels can significantly improve the tensile strength and thermal stability of biodegradable films, rendering them appropriate for packaging applications [27]. The successful development of films from banana peels not only addresses the issue of plastic waste but also provides an added value to agricultural by-products [36, 56]. The creation of films derived from banana peels employs a variety of methods, including the addition of fillers such as starch, citric acid, and plasticizers, which enhance the mechanical characteristics and biodegradability of the films [56, 9]. For instance, Jangra et al. (2023) illustrated that the combination of banana peel with industrial maize starch resulted in bioplastic films that decomposed within a week, offering a promising substitute for traditional plastics [25]. These results are consistent with findings from other research, which emphasize the potential of banana peel powder as a reinforcing agent to improve the physical and chemical attributes of biodegradable films [21]. Additionally, investigations have concentrated on the characterization of banana peel-based films to assess their applicability in industrial settings. Research indicates that these films possess remarkable water vapor permeability, tensile strength, and thermal stability, all of which are essential for food packaging materials [30, 53]. Furthermore, the incorporation of plasticizers such as glycerol has been shown to enhance the flexibility of the films, facilitating their handling and making them more appropriate for packaging uses [7, 44, 52].

Innovative approaches in this field have also included the integration of banana peel biopolymers with other substances, such as cellulose nanofibers and bacterial cellulose. These combinations have demonstrated a significant improvement in the mechanical and barrier properties of the films, rendering them more robust and resistant to environmental challenges [8, 31]. Such developments highlight the potential of banana peel films as a sustainable alternative to petroleum-based plastics within the packaging sector. The development of biodegradable films derived from banana peels has shown considerable promise; however, several challenges persist. A primary concern is ensuring that these films satisfy the stringent requirements for industrial applications, particularly regarding mechanical strength, thermal stability, and biodegradability. Recent research has suggested the need for additional studies focused on optimizing processing conditions and formulations to improve the characteristics of these films [35]. For example, incorporating citric acid has been found to enhance the tensile strength and durability of banana peel-based films, potentially addressing some of the existing challenges [18, 40]. Biodegradable films produced from banana peels signify a notable progress in sustainable material development. These films offer a viable alternative to conventional plastics and contribute to the recycling of agricultural waste. Although further research is required to improve their properties for commercial use, current studies indicate that films made from banana peels could transform the packaging sector by offering an eco-friendly solution to the issues associated with plastic waste.

## 2. COMPOSITION OF BANANA PEEL

The composition of banana peel is characterized by a diverse array of bioactive compounds, nutrients, and fibers, which enhance its potential uses across various sectors, including food, agriculture, and pharmaceuticals. Notably, banana peels are abundant in dietary fibers, which constitute approximately 40-50% of their total content. These fibers comprise cellulose, hemicelluloses, and lignin, with notable differences influenced by the banana variety and its ripeness. The substantial fiber content is beneficial for promoting digestive health and reducing cholesterol levels [12, 19]. Green banana peels are particularly high in resistant starch, containing around 22.6% starch. As the banana matures, this starch undergoes conversion into sugars through enzymatic processes [29,11]. Over 40 unique phenolic compounds, encompassing flavonoids and tannins, have been identified in banana peels. These compounds are recognized for their potent antioxidant and antimicrobial properties, which are associated with a range of health benefits. Significant concentrations of notable polyphenols, including catechin, gallic acid, and quercetin, have also been observed [59, 43]. Furthermore, banana peels contain 8-11% protein, with essential amino acids like leucine, valine, phenylalanine, and threonine present in considerable amounts. Lysine is identified as a limiting amino acid in banana peels [12]. The lipid content in these peels ranges from 0.90% to 10.44%, with a predominance of polyunsaturated fatty acids, particularly linoleic acid and α-linolenic acid. These fatty acids enhance the nutritional profile of the peels and suggest their potential applications in skincare and therapeutic fields [2, 39]. Additionally, banana peels are abundant in essential minerals, with potassium being the most prevalent, followed by calcium, magnesium, and phosphorus. These minerals play vital roles in various physiological functions, including muscle contraction and maintaining bone health [2]. Furthermore, banana peels contain approximately 15.89-24.08% pectin, which can be extracted for use as a gelling agent in food products such as jams. The quality of pectin derived from banana peels positions them as a valuable resource for industrial applications [67]. According to another study, the yield of pectin produced was 17.19% [54]. They also contain carotenoids, including lutein, β-carotene, and α-carotene, which not only contribute to the peel's coloration but also offer health benefits, such as supporting eye health and providing antioxidant properties [50]. Overall, banana peels are a rich source of bioactive compounds, fibers, minerals, and other nutrients, making them suitable for a wide range of applications, from dietary supplements to industrial uses.

According to several studies, nutritional component of banana peel is given in the following table-1: [14, 12, 28].

**Table 1 Nutritional Component of Banana Peel**

| Category | Nutritional Component | Range of Average Content (% DM) |
|---|---|---|
| ***Carbohydrates*** | Carbohydrate | 59.51 – 76.58 |
| | Starch | 3.5 – 6.3 |
| | Resistant Starch | 2.3 – 2.5 |
| ***Fibers*** | Dietary Fibre | 47 – 53 |
| ***Proteins & Fats*** | Crude Protein | 5.5 – 7.87 |
| | Crude Fat | 2.24 – 11.6 |
| ***Minerals*** | Ash | 9 – 11 |

Due to its abundant nutritional profile, banana peels have a wide range of applications. An article by H. Mohd Zaini et al. (2022) highlights the multifaceted benefits of banana peels, emphasizing their nutritional components, which include various chemical compounds, fatty acids, amino acids, and dietary fiber [60]. The article also points out their pharmacological advantages, such as antioxidant, antimicrobial, and anticancer effects. Furthermore, the peel contains anti-nutrients, including phytate, alkaloids, oxalate, and glycosides. Ultimately, banana peels serve diverse roles in the food industry, being utilized in food ingredients, products, and packaging, thereby establishing them as a significant resource in both nutrition and industry.

## 3. DEVELOPMENT OF BIODEGRADABLE FILM BASED ON BANANA PEEL

The creation of biodegradable films from banana peels represents an effective method for repurposing food processing byproducts [56]. Among agricultural residues, banana peels remain underutilized. The starch extracted from banana peels can be transformed into biofilm. Given its high amylopectin content, an acid modification process utilizing HCl solution was employed to convert amylopectin into amylose or smaller starch fragments. This modification results in a biofilm characterized by a denser matrix, thereby enhancing the material's tensile strength. Glycerol was incorporated as a low molecular weight plasticizer to increase the free volume of the polymer matrix, facilitating the movement of polymer chains, which subsequently enhances the elongation at break of the biofilm. Films derived from banana peels address a significant challenge in the industry by improving efficiency and simultaneously contributing to the economy through various applications where plastic wrapping is traditionally utilized. These banana-based films can serve as packaging for dried foods, quick-dissolving ingredients, or as wraps and coatings for food products, thereby providing nutritional benefits and convenience while minimizing food packaging waste [37].

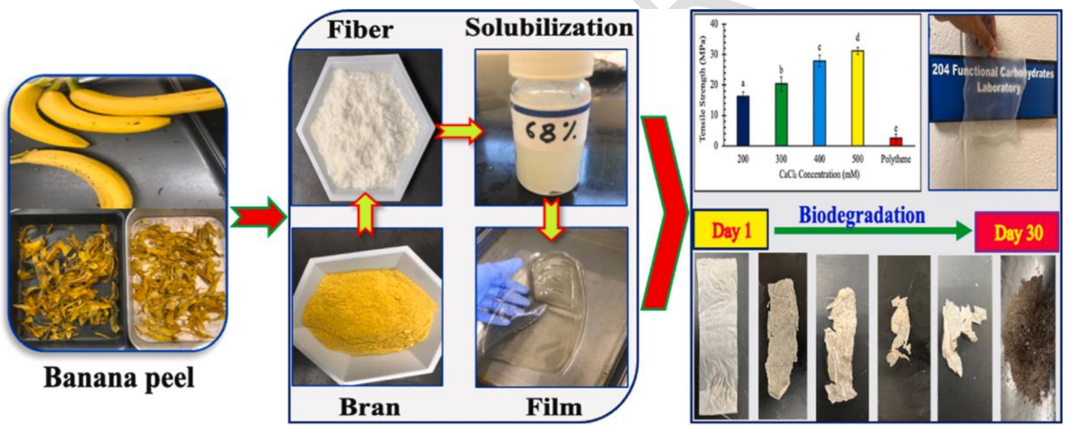


**Fig. 1: Biodegradable packaging films from banana peel fiber [20].**

Banana peel fiber has the potential to contribute to the creation and advancement of biodegradable films, providing an eco-friendly alternative to mitigate the harmful impacts of plastic materials. These films exhibit transparency and demonstrate a tensile strength of 31.3 MPa, with thickness measurements varying between 0.057 mm and 0.090 mm [20].

The addition of nanofibers, such as cellulose nanocrystals (CNCs), or chemical additives like citric acid, has been found to further enhance the properties of these films. Citric acid functions as a crosslinking agent, creating stronger hydrogen bonds that improve mechanical stability and water resistance [40]. Various types of biodegradable films from banana peel can be categorized as follows:

**1.1 Starch-Based Biodegradable Films:** Banana peels, which are abundant in starch, serve as a crucial component in the formulation of biodegradable films. These starch-based films exhibit improved tensile strength and barrier properties, making them ideal for food packaging applications. Numerous studies have focused on optimizing these formulations by incorporating additives such as glycerol to enhance flexibility and citric acid to mitigate browning and bolster film stability [25, 9].

**1.2 Nanocomposites:** The integration of cellulose nanocrystals (CNCs) and other nanomaterials represents a significant advancement in film technology. CNCs contribute to enhanced tensile strength, thermal stability, and water resistance, positioning these films as promising alternatives to traditional packaging materials [34, 63].

**1.3 Pectin-Based Films:** Films derived from pectin extracted from banana peels, in conjunction with various natural additives, create robust crosslinked networks. These films display excellent barrier and mechanical characteristics, particularly when crosslinking agents such as citric acid are incorporated [10].

**1.4 Hybrid Films:** The integration of banana peel starch with other biopolymers, including corn starch or protein isolates, has shown improved biodegradability and strength. For instance, the combination of banana peel with polyvinyl alcohol (PVA) or soy protein has produced resilient, flexible, and environmentally friendly films that are well-suited for packaging and agricultural uses [3, 6].

**Table 2: Biodegradable Films from Banana Peel**

| Type | Formulation of Film Forming Solution | Film Preparation Method | Film Physical Properties | Film Functional Properties | References |
|---|---|---|---|---|---|
| **Starch-based** | Banana peel starch, glycerol, citric acid | Solvent casting | Thickness: 0.387 mm, tensile strength: 10.56 MPa | Water resistance: 63.63%, biodegradable within 1 week | [10] |
| **Nanocomposite** | Banana peel pectin, cellulose nanocrystals (CNCs), citric acid | Solvent casting | Tensile strength: 7.92 MPa, elongation at break: 4.26% | High barrier to water vapor, strong hydrogen bonding | [40] |
| **Starch- based** | Banana peel, corn starch, glycerol, acetic acid | Solvent casting | Tensile strength: 3.50 N, water absorption: 50% | Biodegradable within 7 days | [25] |
| **PVA-based** | Polyvinyl alcohol (PVA), banana peel filler, glycerol | Solvent casting | Tensile strength: 44.5 MPa, Young's modulus: 66.7 GPa | Water absorption: 42.3%, thermally stable up to 300°C | [6] |

| | | | | | |
|---|---|---|---|---|---|
| **Hybrid biopolymer** | Banana peel starch, egg shell, epoxy resin | Casting | Thickness: 0.1-0.15 mm | Bio-degradable, surface roughness supports bio-interaction | [36] |
| **Protein-based** | Soy protein isolate, banana peel cellulose nanofibers | Solution casting | Tensile strength: 1250-1666.67 $N/m^2$ | Biodegradable | [8] |
| **Pectin-based** | Pectin from banana peel, CMC, glycerol, tapioca flour | Solvent casting | Tensile strength: 8.22 MPa, Young's modulus: 0.20347 MPa, Thickness: 1.025 mm, Elongation percentage is 40.4% | Biodegradable, | [30] |
| **Banana Peel/ Corn Starch Blend** | Banana peel, corn starch, glycerol, acetic acid | Solvent casting | Tensile strength: 34.72 $N/m^2$, water absorption: 60.65% | High thermal stability, biodegradable | [51] |
| **Cellulose/Banana Peel Composite** | Cellulose, banana peel powder, plasticizer | Regeneration method | Uniform filler distribution, Tensile strength: 74.16 Mpa, Elongation percentage is 6.85% | Improved thermal stability, suitable for food packaging | [64] |
| **Banana Peel starch based** | Banana peel starch, citric acid, glycerol | Casting | Tensile strength: 4.202 MPa (with $CaCO_3$), improved flexibility | Biodegradable, stronger with crosslinking agents | [18] |

| | | | | | |
|---|---|---|---|---|---|
| **Banana Starch Composite film** | Banana peel starch, eggshell, orange waste, glycerol | Solvent casting | Tickness: 0.07 mm, Porous structure, water solubility: 20.10%, high adsorption capacity | Used as biosorbent for heavy metal removal, water barrier properties, improved adsorption capacity | [58] |
| **Banana Peel Edible Film** | Banana peel, acetic acid, glycerol, plasticizer | Solvent casting | Thickness: 0.90 mm, tensile strength: 1.83 kg/cm$^2$, Elongation at break: 93.73 %, Water solubility 70.11 % | Transparent, flexible, water-soluble | [65] |
| **Banana Peel and Polyvinyl Alcohol (PVA)** | PVA, banana peel waste, glycerol | Solution casting | Tensile strength: 32.52–46.97 MPa | High biodegradability, suitable for daily uses | [35] |
| **Banana Peel and *Eriobotrya Japonica* Film** | Banana peel flour, starch, *Eriobotrya japonica* extract | Solvent casting | Tensile strength reduced with extract addition | Antioxidant properties, good elongation | [49] |
| **Biodegradable Planting Bag** | Banana peel extract, thermoplastic starch | Solvent casting | Tear resistance: 66.388 N/mm | Rapid biodegradation in soil | [22] |
| **Banana Peel Starch** | Banana peel starch, plasticizer | Solvent casting | Degraded at rapid rate | Rapid degradation, viable alternative to plastics | [24] |

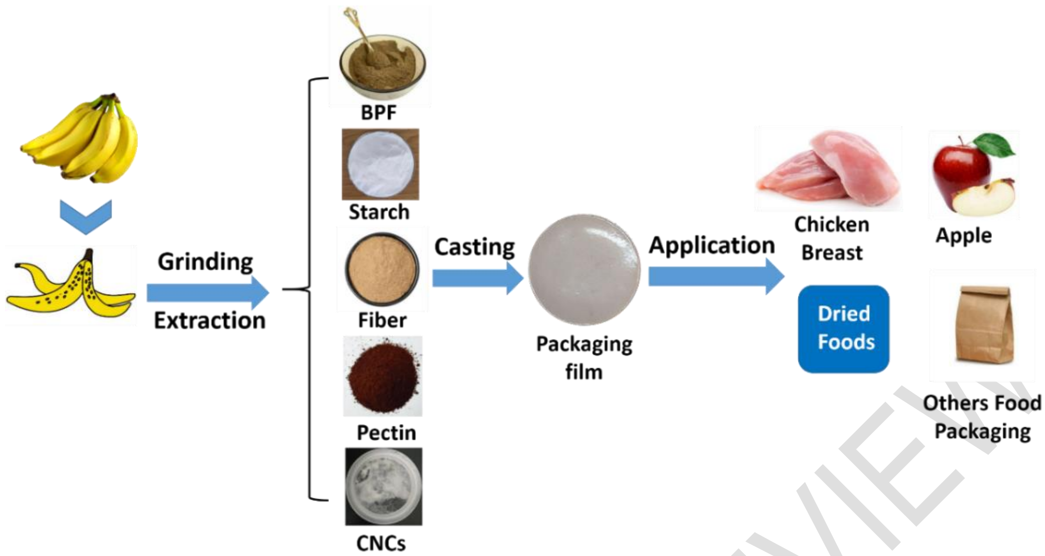


**Fig. 2: Application of Banana Peel to Food Packaging [46, 61, 49, 47, 18, 20, 8].**

Banana peel-derived edible films, infused with spices such as cumin, oregano, garlic, and pepper, were utilized as wraps for grilled chicken. This film enhanced the chicken's shelf life by minimizing microbial proliferation and creating a barrier against oxidation during refrigerated storage [46]. Additionally, a composite film formulated from chitosan and banana peel extract served as a coating to maintain the quality of apples during storage. This film demonstrated antioxidant properties, which contributed to preserving freshness and preventing oxidative damage [61]. Films produced from banana peel cellulose nanofibers were developed for biodegradable food packaging. These films displayed improved mechanical strength and biodegradability, making them appropriate for various food packaging needs [8]. A study's findings indicate that banana film may serve as an appropriate edible packaging solution for dried foods, instant water-soluble ingredients, or as a wrap or coating for food products. This innovation could enhance nutritional value and convenience for consumers while simultaneously minimizing food packaging waste [47]. Furthermore, banana peel and starch films enhanced with extracts from *Eriobotrya japonica* leaves, might be applied to the coating of perishable foods aiming to increase shelf-life minimizing spoilage, and providing antioxidant protection [49]. These examples highlight the adaptability of banana peel-based biodegradable films in food preservation and packaging, presenting sustainable and environmentally friendly alternatives to traditional plastics.

## 4. BENEFITS OF USING BANANA PEEL BASED COMPONENTS IN PACKAGING DEVELOPMENT

Banana peel-derived materials have been investigated for their potential advantages in the development of packaging solutions [62]. As a plentiful agricultural byproduct, banana peel can be transformed into biodegradable packaging options, thereby diminishing dependence on conventional plastics and mitigating environmental pollution [4]. Films produced from banana peel composites are characterized by their lightweight and robust nature, positioning them as a feasible substitute for high-density polyethylene (HDPE) and polystyrene plastics [26]. Bioplastics produced from banana peels demonstrate commendable mechanical strength and thermal stability; however, their performance may not consistently surpass that of all synthetic plastics across all parameters, especially in high-performance applications that demand exceptional durability [5]. For instance, composites of cellulose and banana peel powder reveal superior tensile and thermal characteristics, rendering them appropriate for packaging uses [13]. The addition of banana peel extracts to films boosts their antioxidant and antimicrobial properties, thereby prolonging the shelf life of food items. These films can serve as active packaging solutions, such as chitosan films enriched with banana peel extracts, which have shown effectiveness in maintaining the postharvest quality of fruits [61]. The application of banana peels in packaging not only minimizes waste but also offers an economical alternative to traditional materials. Research indicates that banana peel biocomposites are cost-effective and straightforward to manufacture, providing a sustainable option for industries in search of budget-friendly packaging solutions [45].

## 5. LIMITATION OF USING BANANA PEEL BASED BIOPLASTIC

Banana peel-based bioplastics offer a promising environmentally friendly alternative to petroleum-based plastics, showcasing superior tensile strength, Young's modulus, and resistance to various testing parameters [1, 57]. However, there are limitations to consider when comparing them to petroleum-based plastics. While banana peel bioplastics exhibit biodegradability and some chemical resistance similar to traditional plastics [16], they may have lower water absorption and elongation properties [1]. Additionally, the mechanical properties of banana peel bioplastics can be enhanced by adding chitosan and glycerol [13]. Despite these enhancements, banana peel-based bioplastics may still face challenges in achieving the same level of mechanical strength and versatility as petroleum-based plastics, which have been widely used in various industries for their durability and flexibility [66, 23].

## 6. CONCLUSION

Recent developments in the creation of biodegradable films from banana peels demonstrate their potential as an environmentally friendly substitute for synthetic plastics. These films possess remarkable biodegradability and favorable mechanical characteristics, making them ideal for uses in packaging and agriculture. They are capable of breaking down naturally within a matter of weeks, thus offering a practical method to mitigate plastic waste. Enhancing specific properties such as tensile strength and water vapor permeability may allow for expanded industrial applications. Bioplastics diminish dependence on fossil fuels and enhance the carbon footprint, contributing to environmental conservation and resource efficiency, particularly within the packaging sector. Additionally, they provide advantages in agriculture by breaking down to stabilize root temperatures, preserve soil nutrients and moisture, and promote plant development [72]. The manufacture of these films represents a significant opportunity to decrease ecological impact by repurposing agricultural by products [25, 10, 41, 30].

## 7. FUTURE PERSPECTIVES

The future outlook for biodegradable films made from banana peels is highly encouraging, with numerous advancements anticipated to enhance their functionality and effectiveness in packaging applications. Upcoming research will aim to strengthen the mechanical characteristics of banana peel films by fine-tuning the concentration of reinforcing agents, such as cellulose nanofibers, to ensure these films can achieve comparable strength and durability to synthetic plastics [8]. Additionally, further innovations are expected to improve the water resistance and barrier properties of banana peel films through chemical modifications, thereby increasing their suitability for food packaging purposes [40]. However, the scalability of banana peel films for industrial production presents a significant challenge. Future initiatives will concentrate on creating cost-effective and energy-efficient methods for large-scale manufacturing [25]. Scientists are likely to explore using banana peel films as a packaging material by adding antimicrobial agents to them, which could potentially extend the shelf life of perishable foods by actively inhibiting the growth of bacteria on the food surface, creating a more effective active packaging solution [39, 53]. In summary, with advancements in mechanical, barrier, and functional properties, banana peel films represent a significant sustainable alternative to conventional synthetic plastics.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

We hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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