Development and Characterization of Bioplastic from *Citrus sinensis* (Orange) and *Musa paradisiaca* (Banana) Peels as a Sustainable Alternative to Conventional Plastics

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Abstract— The present work investigates the development and assessment of biodegradable plastic with *Citrus sinensis L.*, also called as Orange and *Musa paradisiaca L., also called* Banana peels as raw materials. The bioplastic was prepared with an easy method by treating the peels with sodium bisulfite, acid hydrolysis, plasticizing using glycerol, and adding clove oil for antimicrobial activity. The sample exhibited excellent mouldability and chemical stability, being insoluble in water, concentrated acid, and alcohol. Mechanical analysis showed that an elongation ratio which was a sign of moderate flexibility. A high biodegradation rate within two weeks in soil was a validation of its eco-friendly character. It can be concluded that this bioplastic derived from fruit peel is a tough, flexible, and biodegradable substitute for regular plastics. It offers distinct benefits like cost-effectiveness, sustainability, and lower environmental footprints through the use of agro-waste. This bioplastic has the potential to be applied in packaging and disposable products as the world moves towards cleaner materials and circular economy processes. *(Abstract)*

***Index Terms*—Bioplastic, flexibility, biodegradation, sustainable.** *(key words)*

I. Introduction

As environmental concerns surrounding traditional petroleum-based plastics continue to rise, the hunt for eco-friendly alternatives has intensified. Bioplastics, sourced from renewable biomass, are being recognized as a viable option to help reduce plastic waste and lessen our reliance on fossil fuels [1]. Among the various organic waste materials, fruit peels especially those from bananas and oranges are particularly interesting due to their abundance and high levels of biodegradable polymers [3].

Musa paradisiaca L. (Banana) yellow peels represent about 30–40% of the fruit's total weight and are mainly made up of cellulose, hemicellulose, lignin, starch, and pectin, essential ingredients in the creation of bioplastics [8]. They also contain significant amounts of dietary fibers, proteins, and lipids, which can enhance the mechanical properties of the bioplastics produced [2, 8]. Impressively, bioplastics derived from banana peels have shown remarkable tensile strength and flexibility, making them ideal for uses like packaging materials [3].

Citrus sinensis L. (Orange) peels, often tossed aside as waste in the agro-industrial world, are actually packed with cellulose and other polysaccharides [4]. Research has shown that bioplastics made from orange peels have impressive qualities, like flexibility, reduced porosity, and the ability to biodegrade when composted [5]. Plus, when you mix orange peel powder into biopolymer matrices, it boosts the strength and water resistance of the films, making them even more useful for food packaging [6]. The mineral content in banana and orange peels enhances the functionality of these bioplastics. For instance, banana peels are rich in potassium (4.50 mg/g) and manganese (6.57 µg/g), while orange peels have higher levels of calcium (1.19 mg/g) and strontium (7.92 µg/g) [7]. These minerals not only enrich the nutritional value of the bioplastics especially when used for food applications but they also influence the mechanical and thermal properties of the materials.

From a financial perspective, using banana and orange peels to create bioplastics is a cost-effective approach that also helps make good use of agricultural waste [2, 4]. This not only reduces the negative effects of waste disposal on the environment but also paves the way for developing countries to embrace sustainable manufacturing practices. Since these bioplastics are biodegradable, they contribute to less long-term pollution, aligning with global efforts toward a circular economy [1, 3]. Turning orange and banana peels into bioplastics presents a multifaceted challenge that addresses environmental, economic, and health-related issues. The natural qualities of these fruit peels, like their polymeric structure and mineral content, make them suitable for creating biodegradable products with a range of uses. Ongoing research and development in this field could be the key to widespread adoption of bioplastics made from fruit peels, significantly advancing sustainable development initiatives.

II. Materials and Methods

A) Preparation of the Bioplastic: Biodisposable plastic specimens were manufactured for this research by utilizing organic wastage materials and some chemical reagents. The main raw materials used were 25 grams of orange peel and 25 grams of banana peel, which were thoroughly cleaned, dried, and powdered before they could be processed. A 0.5% Sodium Bisulfite solution ($Na_2S_2O_5$) was applied for 45 minutes to avoid oxidation and maintain the fibrous nature of the peels during pretreatment [9]. After which peels are boiled in distilled water for 30 minutes, completely dried and blended to form thick paste. Addition of 3.0 ml 1.0 N Hydrochloric acid (HCl) supported hydrolysis, helping to deconstruct lignocellulosic compounds [10]. Further, 1.0 ml Glycerol, widely applied as a plasticizer, was added to impart flexibility and hardness to the bioplastic film [11]. Lastly, 3.0 ml of 1.0 N Sodium hydroxide (NaOH) was used for alkaline treatment to enhance cellulose recovery and efficiency of bioplastic preparation [12]. For the provision of antimicrobial activity and shelf-life extension, 2 % clove oil was incorporated into the formula. Clove oil, which contains eugenol, is reported to contain antibacterial as well as antifungal activity and is thus a candidate for application in biodegradable films for packaging food products [13]. The resultant mixture **(Fig. 1)** is sun-dried for 4-6 hours. Analytical grade chemicals ordered from recognized labs were used throughout the experiments.

B) The bioplastic prepared was put through several tests for assessing its functionality. For mouldability, the sample was heated and compressed into various moulds to see how well it holds shape [14].

C) The swelling capacity is assessed by immersing the sample in distilled water, chloroform and absolute ethanol for 2.0 hours. Final weights were taken after drying to assess swelling [15].

D) Testing for solubility involved soaking weighed samples in distilled water, concentrated sulphuric acid, and absolute ethanol [15].

E) Elongation was determined by stretching measured bioplastic strips and computing the percentage elongation with the help of the formula: % Elongation = [(Final length − Initial length) / Initial length] × 100 [14].

F) For examining biodegradability potential, bioplastic was kept 5.0 cm beneath garden soil. Weight loss was monitored every three days for 15 days to ascertain the rate of degradation under ambient conditions [14]. The tests assisted in assessing the mechanical, chemical, and ecological behavior of the bioplastic.

III. RESULTS AND DISCUSSION

The initial weight of the bioplastic **(Fig. 2)** was recorded at 1.419 grams. Moulding test **(Fig. 3)** indicates its capability to be shaped into various forms. This reflects its plasticity and production versatility desirable for use in packaged products and molded goods. The swelling test showed a minor increase in weight of the sample when immersed in water compared to organic solvents chloroform and absolute ethanol **(Table 1)**, suggesting the bioplastic's stability in organic solvents. Additionally, the bioplastic proved to be insoluble in water, concentrated sulphuric acid, and absolute ethanol, indicating its durability and chemical stability in different solvents ironically setting it up for applications where moisture and chemical resistance is principal, e.g., food packaging or coating resources. Pre and post elongation, bioplastic's length was recorded as 4.5 cm and 4.7 cm respectively. Following the stretching process, the elongation percentage was calculated to be 4.40%, which illustrates its elasticity and characteristic of good tensile strength for light-duty applications, like disposable bags or agricultural films. A notable 63.00 % reduction in weight was observed over 15 days in garden soil **(Table 2)**, confirming that the bioplastic is biodegradable due to soil microbial enzymes, which is a positive factor for the long-term environmental footprint, positioning it as a potential eco-friendly substitute for traditional plastics.

IV. CONCLUSION

The research proves that bioplastic produced from *Citrus sinensis L.* (Orange) and *Musa paradisiaca L.* (Banana) peels shows good characteristics like mouldability, chemical stability, mild elasticity, and biodegradability. Its water, acid, and ethanol insolubility demonstrated its strength, while a 63.00 % reduction in weight in soil proves its environmentally-friendly breakdown. With an elongation capacity of 4.40 % and flexibility in shaping, this bioplastic presents a viable option over traditional plastics. Also, it is made from agricultural waste, hence proves to be cost-saving and sustainable. Such benefits justify its likely use in packaging and disposable products for environmental conservation and recycling waste management.

Figures and Tables

Fig. 1. Orange and Banana peel Bioplastic (before drying)

Fig. 2. Orange and Banana peel Bioplastic (after complete drying)

Fig. 3. Test for Mouldability

TABLE 1 SWELLING TEST OF BIOPLASTIC

Solvents used	Weight of bioplastic in grams		
	Initial Weight (before immersing)	**Final Weight (after 2.0 hours in solvent)**	**Difference (Final weight-Initial Weight)**
Distilled water	0.500	0.758	0.258
Chloroform	0.500	0.533	0.033
Absolute ethanol	0.500	0.567	0.067

TABLE 2 BIODEGRADATION TEST OF BIOPLASTIC

Days in garden soil	Weight of bioplastic in grams
00	0.334
03	0.261
06	0.232
09	0.191
12	0.152
15	0.125

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