Effect of Silver nanoparticles on the biodegradation of Banana Peel based Bioplastics

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***Abstract*— Bioplastics were prepared from banana peel extract. The biodegradability of the prepared bioplastics in soil and the shelf-life of bioplastics was investigated. Silver nanoparticles (AgNPs) were prepared using leaves of *Ocimum tenuiflorum* (Tulsi) extract. The AgNPs were characterized using XRD. The average particle size was 17. 185 nm. Another set of bioplastics from banana peel extract was prepared by incorporating the prepared AgNPs. The biodegradability and shelf-life of these bioplastics were compared with virgin samples. The bioplastic was observed to have a shelf life of 10 days only. But the shelf life of the silver nanoparticles incorporated bioplastic increased to 15 days. The silver nanoparticles incorporated bioplastics showed lesser soil degradation (37.54%) compared to the virgin bioplastic (49.97 %).**

***Index Terms*— Banana peel, Biodegradation, Bioplastics, shelf-life, soil degradation, silver nanoparticles, *Ocimum tenuiflorum*.**

I. INTRODUCTION

Plastics have become an essential part of our lives. Products that are essential for daily living are made of plastic. Plastics are also used in practically every industrial sector. Petrochemical-based plastics are often utilised in our daily life because of their adaptability, affordability, light weight nature, and superior thermal properties. However, they are not environmentally friendly due to their significant carbon footprint. Numerous issues are brought on by petrochemical-based products [1], such as the build-up of garbage on land and in natural environments like the sea and oceans [2]-[4]. There have been numerous initiatives to minimise the use of plastic and also to recycle plastic products.

In these conditions, both the decision-makers and the plastics sector are very interested in replacing the non-biodegradable petrochemical plastics with biodegradable and/or renewable resource-based plastics [5]- [7].

Bioplastics are biodegradable plastics and/or are made from biological sources rather than fossil fuels. Similar to traditional plastics, bioplastics have a variety of uses in everyday situations [8]-[9]. The bioplastics' only distinction is that they are made of biodegradable or biobased polymers. The biodegradable polymers can be mineralized into water and carbon dioxide by the activity of microbes in a reasonable amount of time. The term "biodegradable plastics" refers to polymers that, when exposed to microorganisms, undergo physical and chemical deterioration and entirely breakdown into methane during anaerobic processes and carbon dioxide during aerobic processes, respectively. The amount of time needed for a substance to completely decompose depends on the material, the environment (such as temperature and moisture), and the location of the decomposition. Algae, fungi, and bacteria have the ability to break down bio-based plastics.

Bioplastics offer distinctive qualities [10]. They have a smaller carbon footprint and are environmentally benign, compostable, biodegradable, and energy efficient [11]-[13]. Bioplastics are employed as packaging materials. By enhancement of its properties, they can be used to create a variety of items, including electronics and automobile parts [14] - [16].

In recent years, there has been a strong push to employ innovative methods for producing bioplastics that encourage sustainable solutions and cut down on plastic waste. Commercially, different starches are used to make bioplastics [14] [17]. Sources that are renewable [18], including oats, corn [19]-[20], wheat, rice, and oats, fibres made from pineapple, jute, hemp, banana stems [21]-[22], cassava [23] and waste paper are used. Starch based plastics [14] decompose quickly and hence we can shield our environment from dangerous toxins by employing plastics made of starch.

Fresh produce and other products with a short shelf life, including vegetables, are packaged with bioplastics. Both products with a short shelf life, like fresh produce and vegetables, and products with a long shelf life, like pasta and potato chips, are packaged with bioplastics [24]-[27]. Food packaging, agricultural foils, textiles, and construction; all use starch-based bioplastics.

We can also make bioplastics from inedible parts of fruits and vegetables in the modern world where food is a scarce resource. Bioplastic is created using food wastes including potato peel, banana peel [22], orange peel, and pomegranate peel.

In this work, we prepared biodegradable bioplastics from banana peel extract as a possible substitute for the conventional plastics [28]. We also investigated the effect of AgNPs on the biodegradability and shelf life of the bioplastic. AgNPs were prepared by green method from leaves of *Ocimum tenuiflorum* **(**Tulsi) extract [29]. The antimicrobial activity of AgNPs is expected to increase the shelf-life of the bioplastics. Such bioplastics can be even used in food packaging [30] [31].

II. MATERIALS AND METHODS

A. Materials

Banana peels were obtained from local food stalls. Hydrochloric acid, Sodium hydroxide, Glycerol and Silver nitrate was obtained from Nice Chemicals Pvt. Ltd. *Ocimum tenuiflorum* was collected locally.

B. Green synthesis of AgNPs from of Ocimum tenuiflorum leaves

Healthy plant samples were collected and thoroughly cleaned in running tap water. The samples were allowed to dry at room temperature. The plant leaves were weighed out and were cut into small pieces. About 40 gm of these finely cut pieces were then mixed with 200 mL distilled water. This mixture was kept for boiling for 30 minutes. After cooling to room temperature, it was filtered. 100 ml of the aqueous solution of plant extract was added to 50 mL of 1 M silver nitrate solution. The solution was allowed to react at room temperature. AgNPs formed were allowed to settle down. It was then filtered washed and dried. The different stages of synthesis are shown in fig. 1.

Fig. 1 Preparation stages of silver nanoparticles from *Ocimum tenuiflorum* leaves

C. Preparation of Banana peel extract

Banana peels were manually removed from the edible portion of the banana and cut into smaller sizes in the range of 2 ± 0.5 cm in length. These banana peels were boiled in water for about 30 minutes. Water was decanted from the beaker and the peels were left to dry on filter paper for about 1-2 hours. After complete drying the peels were transferred to a grinder and ground well to form a paste (fig. 2).

Fig. 2 Ground banana peels

D. Preparation of bioplastic film from banana peel extract

25 gm of banana peel extract was placed in a beaker and 3 ml of 0.1 N HCl was added to this mixture and stirred using a glass rod, followed by 3 ml glycerol and stirred. 0.1 N NaOH was added in order to neutralize and the pH was maintained at 7. The mixture was poured on a glass petri plate which was placed in the oven at 130 °C and was baked till dry. Later, the petri plate was allowed to cool and the plastic film was peeled off from the surface. The photographs of these different stages of preparation are shown in fig. 3.

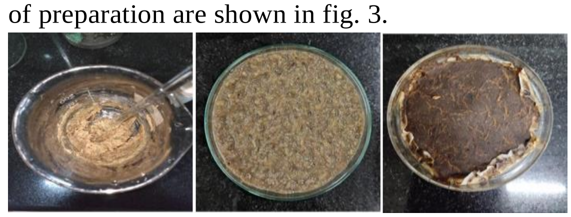

Fig. 3 Preparation stages of banana peel based bioplastic

E. Preparation of AgNPs incorporated bioplastic

Another sample of bioplastic mixture (as explained in section 2.4) was prepared and to this, 0.06 gm AgNPs were added. The mixture poured on a petri plate was kept in oven at 130 °C and baked till dry. Later the petri plate was allowed to cool and the plastic film (nanoparticle incorporated bioplastic) was peeled off from the plate.

F. Biodegradability studies: Soil degradation

Approximately 0.4 gm of a pre-weighed piece of bioplastic was taken and was placed inside a beaker containing soil at a depth of 5 cm from the surface (fig. 4). Water was sprinkled on the soil so that bacterialenzymatic activities could be enriched. These samples were kept in the beaker for 9 days and the weight of the bioplastic was noted every three days.

Fig. 4 Soil degradation studies

G. Shelf life of the prepared bioplastics

The bioplastic samples were kept in the open to check the shelf life. The samples were observed every 3 days for any fungal/bacterial action and photographs were taken.

III. RESULTS AND DISCUSSION

A. XRD of the prepared AgNPs

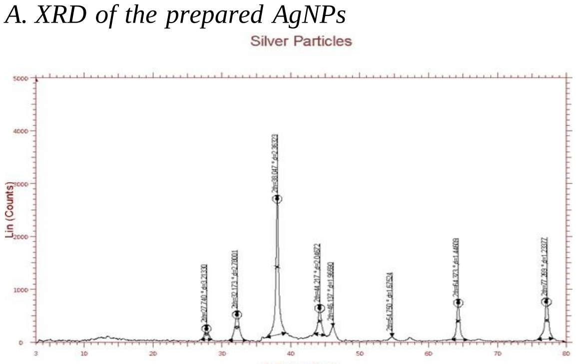

Fig: 5 XRD analysis of the prepared AgNPs

The X-Ray diffraction patterns of silver nanoparticles synthesized by green synthesis method from *Ocimum tenuiflorum* plant extract is shown in fig. 5. The XRD analysis showed diffraction peaks corresponding to fcc structure of silver. Intense peaks were observed at 2θ values of 38.042°, 44.212°, 64.369°, and 77.271°, corresponding to 111, 200, 220, and 311 Bragg's reflection, respectively (JCPDS card file no. 03-0921). Thebroadening of the Bragg peaks indicates the formation of nanoparticles. Full width at half maximum (FWHM) data was used with Scherrer's formula to determine the average particle size.

Average particle size was estimated by using Debye-Scherrer formula, $D = \frac{0.9\,\lambda}{B\cos\theta}$ where λ is the wavelength of X-ray (0.1541nm), B is FWHM (full width at half maximum), θ is the diffraction angle and D is the particle diameter size. The calculated particle size is depicted in table no:1. The value of d (the interplanar spacing between the atoms) is calculated using Bragg's law, 2dsinθ = n λ. The average particle size estimated was 17.185 nm.

Table: 1 Particle size calculation of AgNPs

2θ of the intense peak	hkl	FWHM Of intense peak	Size of the particle (D) Nm	d-spacing nm	Lattice Paramparа (a)	Average particle size
38.042	(111)	0.0066497	20.8515	0.236	0.4088	17.185 nm
44.212	(200)	0.0085521	16.2132	0.205	0.41	
64.369	(220)	0.0079063	17.5380	0.145	0.4101	
77.271	(311)	0.009808	14.1378	0.124	0.4122	

B. Biodegradability studies: Soil degradation

The soil degradation of the prepared bioplastics was studied and the results are listed in table2. The prepared bioplastic showed 49.97 % degradation from the initial weight after 9 days. The nanoparticles incorporated bioplastic showed a lesser degradation of 37. 54 %. This means that AgNPs provides an antibacterial action to the bioplastic and slows down the biodegradation. It does not entirely eliminate the biodegradation. Yet, the bioplastic is biodegradable. The incorporation of AgNPs increases the shelf life of the bioplastic without compromising its biodegradability to a great extent. Hence this bioplastic can be considered as a substitute for conventional plastics.

Table 2: Biodegradability of bioplastic material

Sample	Initial quantity taken in grams	Weight after 3 days	Weight after 6 days	Weight after 9 days	Percentage of degradation after 9 days
Bioplastic	0.4200	0.3642	0.2586	0.2101	49.97
Bioplastic incorporated with AgNPs	0.4200	0.3762	0.2858	0.2623	37.54

C. Shelf life of bioplastic

On the 10th day of observation, fungal action was observed on bioplastic without AgNPs. But in sample incorporated with AgNPs, fungal action was observed only on the 15th day. The presence of AgNPs could enhance the shelf-life of the bioplastics. This may be due to the antimicrobial property of AgNPs.

IV. CONCLUSIONS

Banana peel extract could be an effective substrate for the production of starch-based bioplastics, and it will be a feasible solution as a substitute for petroleum-based plastics. In this paper we have analyzed biodegradability of bioplastic produced from banana peel. Later silver nanoparticles were prepared from *Ocimum tenuiflorum* leaf extract. The average particle size of silver nanoparticles determined by XRD was 17.185 nm. These silver nanoparticles were incorporated into the banana peel-based bioplastic and a comparative study was done. Shelf life of the prepared bioplastics were studied. The bioplastic was observed to have a shelf life of 10 days only. But the shelf life of the silver nanoparticles incorporated bioplastic increased to 15 days. This increase in shelf life of the nanoparticle incorporated bioplastic may be due to the effective antibacterial action of silver nanoparticles on the microorganisms. Soil degradation studies of the two samples were conducted. The silver nanoparticles incorporated bioplastics showed lesser degradation (37.54%) compared to the virgin bioplastic (49.97 %).

This means that silver nanoparticles provide an antibacterial action to the bioplastic and slows down the biodegradation. Yet, it does not entirely prevent biodegradation. The bioplastics are biodegradable. The incorporation of silver nanoparticles increases the shelf life of the bioplastic without compromising its biodegradability to a great extent. Hence this bioplastic can be considered as a substitute for conventional plastics without causing any threat to the environment.

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