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ECO- FRIENDLY BIOPLASTIC SYNTHESIS USING VIGNA MUNGO STARCH

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Abstract

The accumulation of conventional plastic waste has led to serious environmental concerns due to the persistence of petroleum-based plastics and their slow degradation in nature. The study focused to develop an eco-friendly and biodegradable plastic film using starch extracted from Vigna mungo seeds as a renewable, plant-based material. The seeds were processed to isolate starch and used for bioplastic preparation with glycerol as a plasticizer, vinegar, and distilled water. The mixture was heated with continuous stirring and cast into thin films for further characterization. The developed bioplastic films were evaluated for solubility, swelling, biodegradability, water absorption, Fourier-transform infrared spectroscopy (FT-IR), and scanning electron microscopy (SEM). The soil burial study demonstrated progressive degradation, with 88.33% weight loss after 30 days, indicating good biodegradability. The water absorption capacity was 21.05%. FT-IR analysis confirmed the presence of important functional groups, including hydroxyl, C–H, C=O, and C–O–C groups, supporting the formation of the starch-based film. SEM analysis revealed changes in surface morphology with increasing magnification, showing improved compactness and reduced porosity. Overall, the findings indicate that Vigna mungo starch has promising potential for producing biodegradable plastic films and can serve as an eco-friendly alternative to conventional plastics, particularly in sustainable packaging.

Keywords: Vigna mungo; starch-based bioplastic; biodegradable plastic; FT-IR; SEM; sustainable packaging.

1. Introduction

The word ‘plastics’ is a colloquial term for a wide range of synthetic or semi-synthetic polymer materials that are used in a growing range of applications. While the first man-made plastic was created in 1862, it was not until the 1940s when industrial production of plastics became possible using fossil fuels as feedstock [1]. Plastic materials are currently considered very important materials due to their properties and performance over other materials such as metal and wood [2].

Plastics serve as a key material in our routine lives due to their durability, versatility, and low cost, the production, consumption, and end of life management of plastics have raised environmental concerns ranging from persistence in the environment, marine debris, human health risks, greenhouse gas emissions. [4-9].

Since, plastic is not biodegradable and will endure in the environment for centuries [10]. In recent years, these environmental problems and social concerns have induced developing environmentally friendly materials such as bioplastics [11].

Bioplastics are novel materials of the 21st century and would be of great importance to the materials world [12]. Generally, “bioplastic” or plant-based bioplastics made from renewable resources such as corn, sugars, potatoes, agricultural waste etc. designed to replace conventional petroleum-based plastics. [13] Biodegradable bioplastics are fully degraded by microorganism without leaving visible toxic remainders, these materials can degrade or break down naturally into biogases and biomass, while being exposed to a microbial environment and humidity, such as the ones found in soil, hence reducing plastic waste, whereas bio-based sustainable materials

[14].

Several plant-derived biopolymers have been developed, including polylactic acid (PLA), polyhydroxyalkanoates (PHA), starch-based bioplastics, bio-polyethylene (bio-PE), and cellulose-based plastics [15]. In the present study, Vigna mungo seeds were used for the preparation and characterization of starch-based bioplastics.

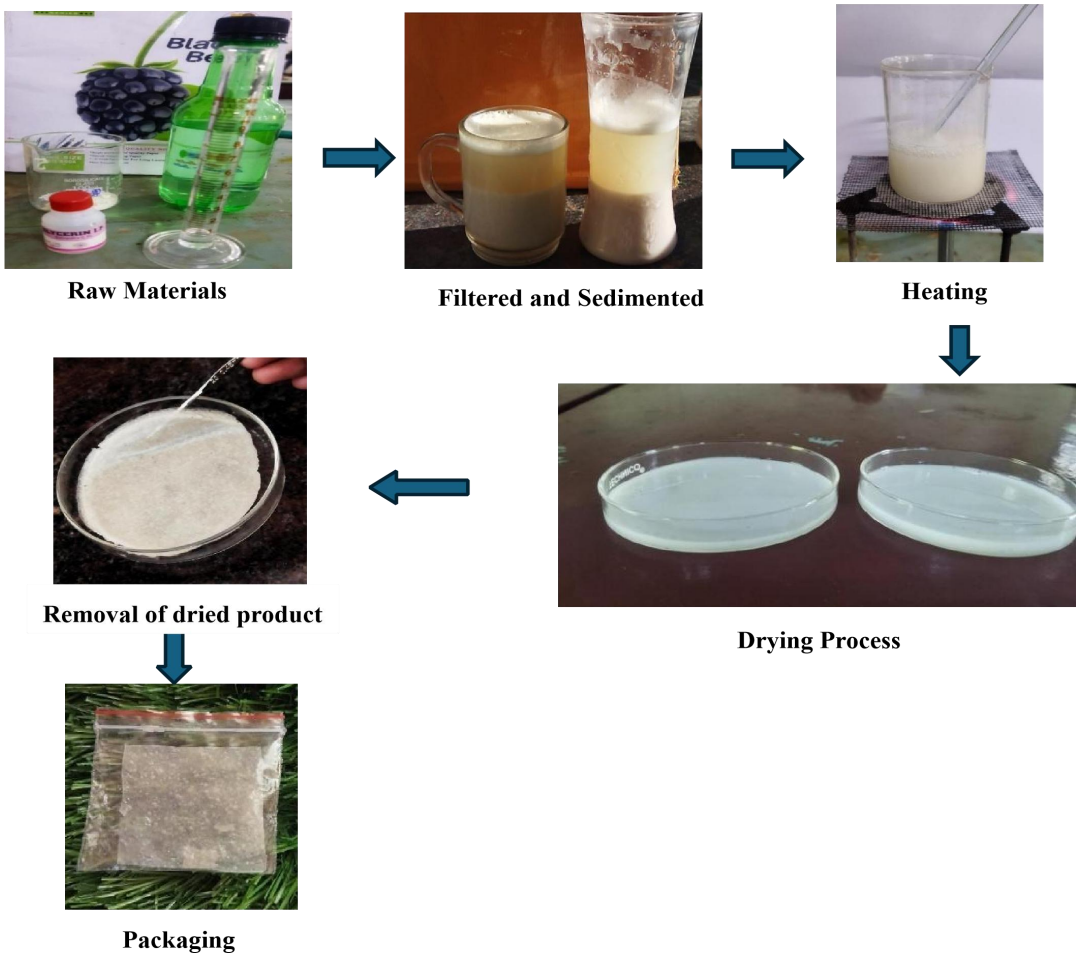
2. MATERIALS AND METHODS

Collection of raw materials

Vigna mungo seeds were procured from local grocery store in Kulasekharam, Tamil Nadu, India. The seeds were thoroughly washed with distilled water to remove foreign debris followed by shade- dried at room temperature for 4- 5 days. The dried seeds were stored at sterile containers for further use.

Requirements

Vigna mungo seeds, Distilled water, Glycerol, Vinegar, Filter paper or cloth, Beaker, Glass rod, Petri dishes.



ISOLATION OF STARCH VIGNA MUNGO

Vigna mungo seeds (100g) were soaked in distilled water for 8-10 hours, drained, and homogenized with distilled water. The slurry was filtered through muslin cloth and allowed to stand for 4–6 h for starch sedimentation. The supernatant was discarded, and the recovered starch was shade-dried at room temperature, powdered, and stored in a sterile container under dry conditions.

BIODEGRADABLE PLASTIC PREPARATION

Biodegradable films were prepared using Vigna mungo starch (6 g), glycerol (5 mL), vinegar (5 mL), and distilled water (100 mL). The mixture was heated with continuous stirring until

viscous and transparent, cast into Petri dishes, and dried at room temperature for 24–48 h. The resulting films were carefully removed and stored in airtight containers. Different formulations were prepared by varying starch, glycerol, vinegar, and water concentrations and evaluated for tensile strength.

3. CHARACTERIZATION

SOLUBILITY TEST:

Solubility tests on bioplastics assess their chemical stability and suitability for specific applications. Small bioplastic pieces were immersed in various solvents like hot water, cold water, sulfuric acid, and aqueous for 24 hours to estimate the bioplastic's activity.

SWELLING TEST:

Swelling tests measures the ability of bioplastics to absorb moisture, oils, and other liquids. Pre-weighed samples were immersed in solvents like aqueous, chloroform, and ethanol for 24 hours. Changes in dimensions and weight were recorded to determine the degree of swelling and observe any morphological changes.

BIODEGRADABILITY TEST:

The bio-plastic materials were cut into pieces, weighed and buried in soil. Required amount of water was sprinkled on the soil so that bacterial enzymatic activities could be enriched. The samples were kept in the soil for about 15 days and each 5 days of interval we observed the decrease in the weight of the samples and results were recorded.

WATER ABSORPTION:

Samples are immersed in water or exposed to high humidity for 24 hours, and their weight is measured to determine the amount of water absorbed.

FOURIER-TRANSFORM INFRARED SPECTROSCOPY

The prepared bio-plastic films were characterised by using FT-IR spectroscopy to identify and analyze the functional groups present in the material, providing vital information on its characteristics, functionality and monitor the degradation and ensures quality of bioplastics. Spectra were recorded at a wavelength in the range of 400 and 4000 cm-1.

DETERMINATION OF MORPHOLOGY

SEM analysis provides brief images of the surface, revealing the arrangement of polymer chains, distribution of components, and structural organization. .

4. RESULTS AND DISCUSSION

SOLUBILITY TEST

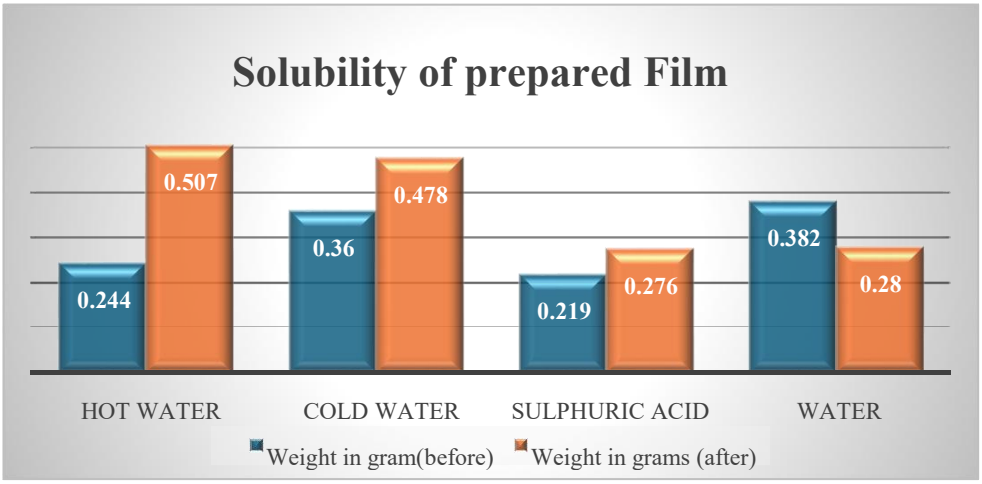
The solubility of prepared bioplastics is given in the table 1.2. Bioplastics is partially soluble in aqueous and insoluble in hot water, cold water and sulphuric acid.

Table 1.2: Solubility of prepared film

Solvents	Weight in gram(before)	Weight in grams (after)
Hot water	0.244	0.507
Cold water	0.360	0.478
Sulphuric acid	0.219	0.276
Water	0.382	0.280

In the present study, solvents water and sulphuric acid revealed excellent solubility result compared to other solvents. Hence, this study corelates with Cordia dichotoma which showed highest solubility nature in sulphuric acid and orthophosphoric acid [17].

Fig: 1.2 Graphical representation for solubility of prepared film



SWELLING TEST

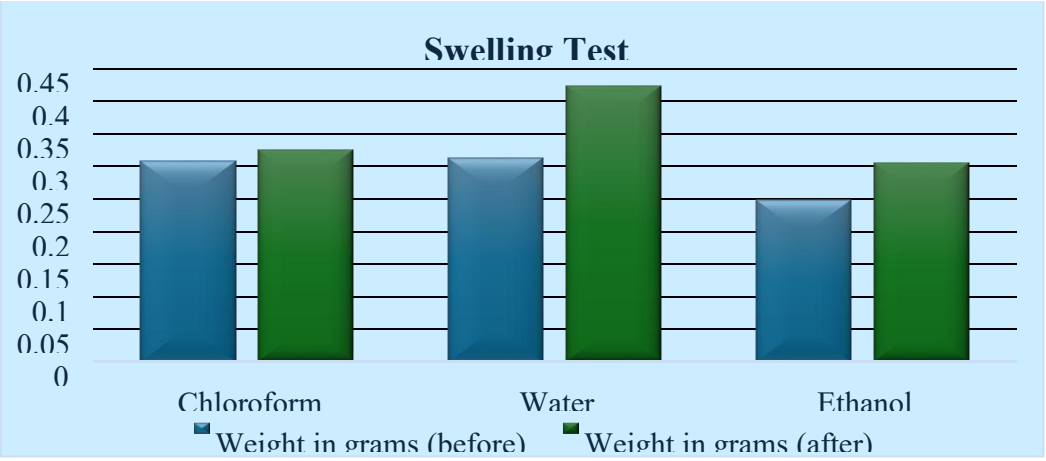
Pre-weighed samples were immersed in solvents such as water, chloroform, ethanol for 2 hours. Sample showed an increase in weight, indicating swelling in each solvent. The maximum swelling was observed in aqueous, signifying strong interface with the bioplastic, due to its hydrophilic nature. Ethanol showed moderate swelling, while chloroform exhibited minimal swelling, indicating lower compatibility with the material.

Table 1.3 Swelling test for prepared film

Solvents	Weight in grams (before)	Weight in grams (after)
Chloroform	0.308	0.325
Aqueous	0.313	0.423
Ethanol	0.248	0.305

The swelling assay revealed the adsorption capacity of Vigna mungo has aqueous, and chloroform has good water adsorption nature. In addition, the study closely corelated with swelling ability of bioplastic attained from Cordia dichotoma has water adsorption nature [17].

Fig: 1.4 Graphical representation for swelling test prepared film



BIODEGRADABILITY TEST:

The sample was cut small pieces weighed and buried in the soil; water is sprinkled to activate enzymatic process. Degradation was noted by weighing sample for each 5 days. Biodegradability was calculated using a specific formula, and the results were recorded in Table 5.3.

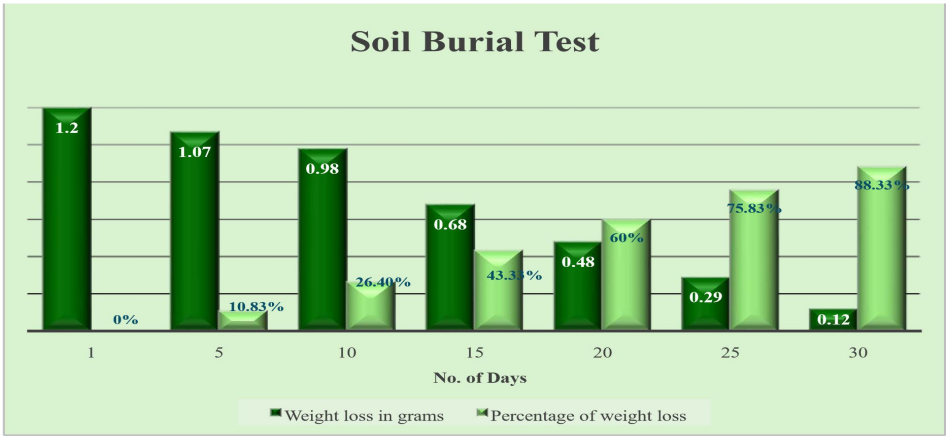
$$Weight\ loss\ (\%) = \frac{W_0 - W_t}{W_0} \times 100$$

Table 1.2: Degradation test by soil burial method

DAYS	Weight loss in grams	Percentage of weight loss
1	1.2	0 %
5	1.07	10.83 %
10	0.98	26.4 %
15	0.68	43.33 %
20	0.48	60 %
25	0.29	75.83 %
30	0.12	88.33 %

After 30 days, the weight loss in grams is noticed with 0.12 grams with 88.3% in Vigna mungo biodegradability Test.The study is co related with Potato starch were the weight of the bioplastic on the sixth day remains 0.112g which exhibited a better biodegradability [18].

Fig. 1.3: Graphical representation of degradation test for prepared bioplastics



WATER ABSORPTION TEST

Sample are cut into pieces and pre-weighed then dipped in distilled water for 24 hours. The weight difference was noted, and water absorption capacity was calculated using the below equation,

$$Absorption = \left(\frac{W_s - W_d}{W_d}\right) \times 100$$

Ws = Saturate weight of the specimen after submersion
Wd = dry weight of the specimen
The water absorption capacity (Weight loss %) of the prepared bioplastic is of 21.0526%

FOURIER-TRANSFORM INFRARED SPECTROSCOPY

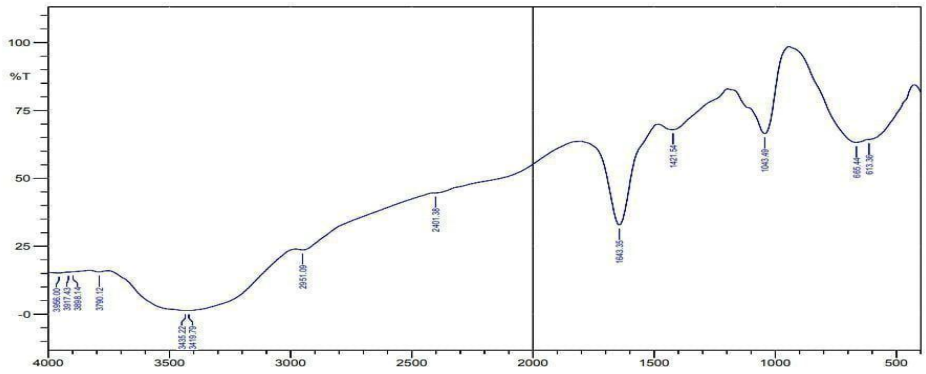
The Fourier Transform Infrared Spectroscopy analysis was carried out to identify the functional groups present in the prepared bioplastic film derived from Vigna mungo starch (Fig. 1.1).

The FT-IR results confirm the presence of functional groups such as hydroxyl, alkane, and ether groups, demonstrating successful modification and formation of the Vigna mungo starch-based bioplastic film.

Table: 1.1 FT-IR Spectrum of Vigna mungo Strach film

Functional group	Wave number (cm-1)
- OH Stretching	3435.22
C- H Stretching	2951.09
C = O bending	1643.35
C - H Stretching	1421.54
C- O- C Stretching	1043.49
C- O Stretching	665.44

Fig. 1.1: FT-IR Spectrum of Strach film



The FTIR spectrum displays absorbance (intensity) as a function of wavenumbers (inverse of wavelength). Peaks at specific wavenumbers may indicate the presence of C-H, O-H, C=O and C-O bonds with 2951.09 cm-1, 3435.22 cm-1, 1643.35 cm-1 and 665.44 cm-1 respectively. The study corelates with, alkane C-H bonds were responsible for the peak at 1632 cm-1, Carboxylic O-H stretching was the cause of the stretching at 3384 cm-1. Peak was ascribed to the C=O stretch at 3146 cm -1 examined in banana peels [19].

SEM (SCANNING ELECTRON MICROSCOPE)

The surface morphology of the prepared bioplastic film was analyzed using Scanning Electron Microscopy at different magnifications (Plates 1–3).

At 1000× magnification (Plate 1), the surface appears heterogeneous and slightly rough, indicating partial aggregation of starch granules and uneven dispersion of components.

At 2500× magnification (Plate 2), the structure shows layered and compact regions, suggesting improved interaction between starch and plasticizer. However, some irregularities and folds are still visible, indicating incomplete uniformity.

At 7000× magnification (Plate 3), the surface becomes comparatively smoother and denser, with fewer visible pores or cracks. This indicates better gelatinization of starch and effective film formation. The reduced porosity suggests enhanced intermolecular bonding and improved structural integrity. The study co relates, Cassava were SEM showed fractured and cracked areas caused by the starch bonds α-1,4-glucosidic connection, which was more amorphous [20].

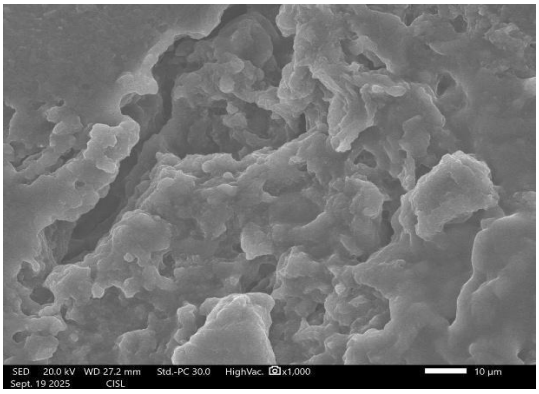


Plate 1. Bioplastic SEM image at x1000 magnification

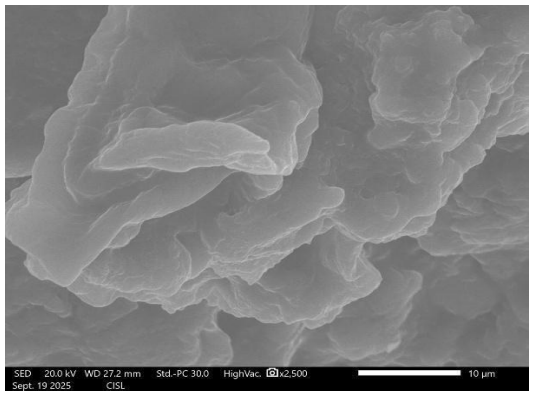


Plate 2. Bioplastic SEM image at x2500 magnification

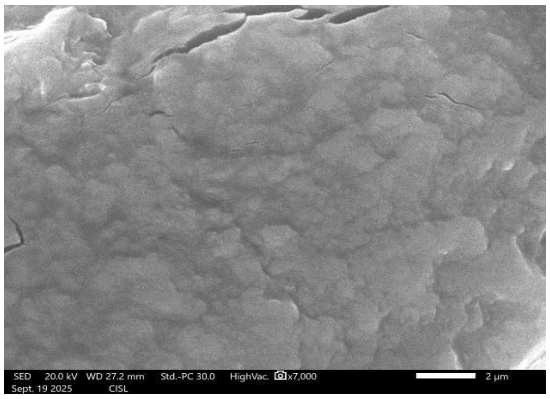


Plate 3. Bioplastic SEM image at x7000 magnification

The SEM observations confirm that the injecting of plasticizers leads to a more continuous matrix, although minor surface irregularities persist. These morphological characteristics directly influence the mechanical strength and biodegradability of the bioplastics.

5. CONCLUSION

Vigna mungo starch derived bioplastics exposed promising characteristics for the use as alternative biodegradable plastics in all versatile industries. They are eco-friendly in nature, surface morphology with SEM analysis confirmed the absence of toxic substances, also the biofilm exposed good texture, flexibility and adaptability. FT-IR spectroscopy revealed the presence of functional groups associated with starch-based bioplastics. Future research and development are needed to improve their properties and production, which helps in packaging industry.

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