

Environmental Management through Characterization of Synthesized Bioplastics Based on Soybean Agro Waste and Identification of Fungi for their Biodegradation

Ayushi Jain^{*1}, Deepika Bhawsar¹, Shailendra Chawda², Gaurav Mali³, Nisha Retrekar⁴, Komal Patil⁵, Sunayana Rathore⁶

^{*1}Faculty of Pharmacy Practice, Indore Institute of Pharmacy, Indore (M.P.) 453331, India Email: ayushi.jain@indoreinstitute.com

¹Faculty of Pharmaceutics, Indore Institute of Pharmacy, Indore (M.P.) 453331, India Email: deepikabhawsar85@gmail.com
Orcid ID 0009-0000-1479-2166

²Faculty of Pharmacy Practice, Radhadevi Ramchandra Mangal Institute of Pharmacy, Neemuch, (M.P.), India
Email: shailendrachawda51@gmail.com

³Faculty of Life Science, Shri S R Education College (M.P.) 458441, India Email: gouravmali709@gmail.com

⁴Faculty of Pharmacognosy, Indore Institute of Pharmacy, Indore (M.P.) 453331, India Email: Nisha.retrekar123@gmail.com
Orcid ID 0009-0005-2684-218X

⁵Faculty of Pharmaceutics, Indore Institute of Pharmacy, Indore (M.P.) 453331, India Email: komalmahajan0501@gmail.com
Orcid ID-0009-0003-9320-5397

⁶Associate Professor, Sri Aurobindo Institute of Pharmacy, Indore Email: nenn2212@gmail.com
Orcid ID 0009-0009-0547-8912

Accepted- 11 June, 2025

Revised- 04 July, 2025

Published- 06 Nov, 2025

Corresponding author:

Dr. Ayushi Jain

Email- ayujain626@gmail.com

Orcid Id- 0009-0002-7324-2572.

ABSTRACT

Increasing demand for plastic and its hazardous impact on environment, encouraged researcher to develop biological based plastics as an alternative to petroleum-based plastic. The present study was conducted to synthesize and characterize bioplastics from soybean agro waste and also to identify the responsible fungi for its degradation. Two types of bioplastics were synthesized by mixing soybean agro waste with corn starch and potato starch, respectively, with a specific concentration. Glycerol was added as a plasticizer for bioplastic synthesis. Characterizations were carried out in terms of water absorption capacity, burning test, thermal strength, and mechanical strength. Water absorption test shows that the mass increased up to 112.6% and 118.1% for bioplastics of potato starch and corn starch, respectively which shows a large amount of water uptake by both bioplastics. Both the plastics could tolerate 80 °C for 5 hours proved high thermal strength. On burning both gave a faint smell of soy and glue like substances. When compared for mechanical strength 10 gm corn starch bioplastic could hold more than 80gm weight whereas potato starch bioplastic (10gm) has capacity to hold 50 gm weight. The overall characterization proved soy waste with corn starch as excellent bioplastic, though potato starch could be used for synthesizing soft plastics. Further for their biodegradation, fungi were identified as *penicillium chrysogenum*, *Aspergillus flavus*, *Mucor ramosissimus*, *Fusarium solani*, *Aspergillus niger*, *Penicillium expansum*. The overall conclusion of the work is that the bio-based plastics have exhibited good thermal and mechanical properties with high biodegradability that makes them a suitable alternative for the existing conventional plastics.

KEYWORDS: Bioplastics, Agro waste, Fungi, Characteristics of Bioplastic.

How to Cite: Ayushi Jain, Deepika Bhawsar, Shailendra Chawda, Gaurav Mali, Nisha Retrekar, Komal Patil, Sunayana Rathore, (2025) Environmental Management through Characterization of Synthesized Bioplastics Based on Soybean Agro Waste and Identification of Fungi for their Biodegradation, Vascular and Endovascular Review, Vol.8, No.6s, 299-303.

INTRODUCTION

Petrochemical based plastics are the organic polymers with a wide range from synthetic and semi synthetic. Plasticity is the property of materials which can deform itself into irreversible structure. The demand for plastic has been tremendously increasing since 1950s. Their high production causing problems on dumping site or landfills since they are not biodegradable. Therefore for

solving the issue biological based plastics are in need which could be made from biological waste as well as easily biodegraded by the microflora from the natural environment.

According to a September 2017 report by the Central Pollution Control Board (CPCB), which extrapolated data from 60 major cities, the country generates around 25,940 tonnes of plastic waste a day. About 94 per cent of this comprises thermoplastic, such as PET (polyethylene terephthalate) and PVC (polyvinyl chloride), which is recyclable. The remaining belongs to thermoset and other categories of plastics, such as sheet molding compound (SMC), fibre reinforced plastic (FRP) and multi-layer thermocol, which are non-recyclable. According to the latest report on the Implementation of Plastic Waste Management Rules published in 2016, the plastic waste generated across the country (barring six states where data was not available) is close to 1.6 million tonnes

a year, with almost half of it coming from Maharashtra and Gujarat. However, the volume of plastic waste generated seems suspiciously low when compared with the data of Plastindia Foundation—a body of major associations, organizations and institutions connected with plastics. The Foundation estimates that in 2017-18 alone, India consumed 16.5 million tonnes of plastic. Worse, according to industry body FICCI, 43 per cent of India's plastics are used in packaging and are single-use plastic. Consumption has clearly outstripped India's capacity to recycle (Venkatesh & Kukreti, 2018).

Bioplastic was developed since nineteenth century which is mostly derived from protein from soy bean, corn and potato (Stevens, 2003). The utilization of food waste such as soy waste in bio packaging can provide value added products. Bioplastic are usually made from the mixture of starch, plasticizer and fibers. The chemical contents of starch consist of two macromolecules amylose (linear starch chain) and amylopectin (branched starch chain) which in their natural forms are suitable for the production of bioplastics. Proteins structure consists of very stable three-dimensional networks maintained by inter-chain interactions but do not provide the material with enough plasticity. Thus, a plasticizer was added to help minimize the glass transition temperature and providing mobility to polymeric chains (Sanyang, et al, 2015). Plasticizers are molecules with low molecular weight and low volatility which can reduce intermolecular forces and increase polymer chains mobility. Among the most common plasticizers used in the bioplastic production are including of water, glycerol, propylene glycol and polyethylene glycol. However, due to glycerol excellent properties, it becomes the most choices plasticizer (Irissin-Mangata, et al., 2001). The global market for bio based plastic is dominated by the soy protein. This is because of its low cost, versatile properties, and high quality, make it quite a competitor. Previous study shows that protein-based bioplastic have been proved to decompose in 50 days when buried in the ground (Domenek, et al., 2004). Other than that, Soy bean agro wastes were utilized in some kind of productivity rather than burning.

The aims of the present work are to utilize soy waste in bioplastic production, to study the effect ratio of starch, soy and plasticizer in the bioplastic production. Characterizations of bioplastics were also done on the basis of their water absorption capacity, thermal strength, burning on flame and mechanical strength. Apart from this Fungi responsible for their degradation and decomposition were also identified to estimate them as pathogenic or nonpathogenic to human and its environment.

MATERIALS AND METHODS

Raw Materials

Soy waste was collected from local agriculture field of Mandsaur District. Corn starch and Potato starch were purchased from the local market of Mandsaur city. Glycerol, acetic acid and sodium hypochlorite were supplied from the Biotechnology laboratory, Department of Life Science, Mandsaur University.

Sample Preparation

The soy waste initially went through a bleaching process for three days. The bleaching solvent composed of 70% of distilled water and 30% of sodium hypochlorite. After that, the soy waste and bleaching solvent was separated with conventional sieve before rinsed with distilled water to remove any lingering smell of bleach. The soy waste was dried in the oven for one hour with temperature 100 °C to remove the excess water. Then, it was blended in the conventional blender into the form of powder. Composition of the bioplastic material is represented in Table 1 and 2 respectively.

Table 1: Bioplastic made up of Corn starch

S.no	Materials	Composition	Composition (%)
1	Soy Waste	3gm	0.05
2	Corn starch	9.5gm	0.11
3	Glycerol	5ml	0.07
4	Acetic acid	5ml	0.06
5	Water	60ml	0.71

Table 2: Bioplastic made up of Potato starch

S.no	Materials	Composition(g/ml)	Composition (%)
1	Soy Waste	3gm	0.05
2	Potato starch	9.5gm	0.11
3	Glycerol	5ml	0.07
4	Acetic acid	5ml	0.06
5	Water	60ml	0.71

Starch and soy powder were mixed thoroughly in a 500 ml beaker. Then, the glycerol, CH₃COOH and distilled water are introduced into the beaker. The distilled water act as a solvent for the mixing process to occurs while the glycerol acts as a plasticizing agent. The mixture was mixed in a suitable proportion to obtain an ample viscosity for mixing.

The mixing process was carried out at 25°C and 50 rpm for 10 min (Jerez, et al, 2005). After 5 minutes, the temperature was increased to 140°C while the mixing continues. After the mixtures become more viscous and thickens, it was left to boil for 5 minutes. Next, it was cooled to the room temperature for ease during handling. Some vegetable oil is coated on the surface of the plate to prevent stickiness between the plastic materials and the surface of the plate. The cooled mixture is flattening on the plate before being heated in the oven at 65°C for two hours before peeled carefully.

Characteristics Test Water absorption Capacity

Most important quality for a plastic is water absorption. Water absorption test is used to determine the amount of water absorbed at a specific condition. The following equation is used to calculate percentage of water absorption capacity.

$$\% \text{ of water absorption} = \frac{\text{Wet Weight} - \text{Initial Dry weight}}{\text{Initial Dry Weight}} \times 100$$

Thermal Strength

Thermal strength of the bioplastics was determined by keeping them in hot air oven for 5 hours at 80°C. Each specimen was kept in same condition inside the hot air oven.

Burning Test

This test was carried out by burning the specimen on top of Bunsen burner. The odour, colour of the flame and speed of burning of packaging material was observed and recorded. Each specimen was burned in the same condition and fire strength.

Mechanical Strength

The mechanical strength was determined by loading different weights to 10gm of each type of bioplastic specimen. Sequentially the loads were increased in both the bioplastics for 10 minutes. The maximum load was estimated by the process to determine their mechanical strength.

Identification of Fungi for degradation of Bioplastics

After 20 days of incubation, fungal growth was observed on the bioplastic specimens. The fungal colonies were isolated and inoculated on Potato dextrose agar medium. The pure culture of fungi were identified through staining them with lactophenol blue and observed under 10X and 45X by covering the stain with cover slip.

RESULT AND DISCUSSION

Based on the equation (as presented above), the soy waste bioplastic increase in 112.6% and 118.1% for potato starch and corn starch respectively which shows large amount of water uptake by both the bioplastic, when conditioned in distilled water at room temperature for 24 hours. The group within the protein that present in the soybean waste causes the percentage of water uptake capacity to increase (Chi-Hui Tsou, et. al, 2014). Results indicate that soy waste bioplastic has large water uptake capacity. Generally, water absorption increases with immersion time and finally reaches certain value where there is no more water being absorbed and water content remained constant (Ismaeil, et. al, 2009). It was observed that the specimen still in its initial shape due to the glycerol molecules in the bioplastic are immobilized which provide the strong interaction with starch (Smits, et. al, 1999). Thus, it will increase the flexibility and decrease in brittleness of plasticizer.

Observation for burning test is based on three properties, which are odour release upon burning, colour of the flame and the speed of burning. Upon burning, the materials released a very faint smell of soy and glue-like substance. This is due to the breaking of glycerol and fiber materials in the packaging. This odour however is not too strong and not too uncomfortable to smell.

Thermal strength test proved that the bioplastic has approximately equivalent strength to the petrochemical plastic. Both types of bioplastics could tolerate 80°C for 5 hours. The mechanical strength for both the plastic it was observed that 10 gm of corn starch and potato starch bioplastic can hold 80 gm and 50 gm weight respectively. T concluded that bioplastics made from corn starch have higher strength to hold weight as compared to potato starch bioplastics.

Table 3: Water absorption capacity of Bioplastics

Bioplastics	Water absorption capacity (%)
Corn starch-soy protein based Bioplastics	118.1
Potato starch-soy protein based Bioplastics	112.6

Table 4: Burning characters of Bioplastics

Material	Odour	Colour of Flame	Speed of Burning
Corn starch-soy protein based Bioplastics	Low odour	Yellow orange	Slow
Potato starch-soy protein based Bioplastics	Low odour	Yellow orange	Slow

Table 5: Thermal and mechanical strength of Bioplastics

Bioplastics	Thermal strength (tolerate)	Mechanical Strength (can hold)
Corn starch-soy protein based Bioplastics	80°C for 5 hours	80gm
Potato starch-soy protein based Bioplastics	80°C for 5 hours	10gm

After 20 days of incubation, fungi such as penicillium chrysogenum, *Aspergillus flavus*, *Mucor ramosissimus*, *Fusarium solani*, *Aspergillus niger*, *Penicillium expansum* were observed on the bioplastics as starch used in the development of these bioplastics were good source of nutrients for different types of fungal colonies. Both types of bioplastics were kept in room temperature with similar conditions. The fungi were identified through by studying their colony characters and staining through the standard methods (Presscot, 2011) represented through the figures given below.

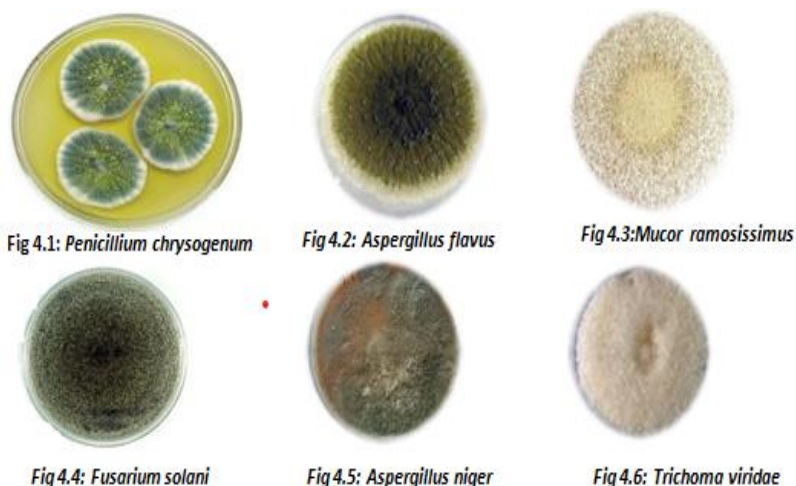


Figure: Identified fungi of bioplastics

The present work concluded that alternative to petro based plastics called bioplastics could be developed with a good quality and could be used efficiently. It could remove the problems of dumping. From the overall result obtained, it proof that soy waste materials may be useful for a lot more than a packaging materials. It is apparently that soy waste, being a by-product from the soy agroindustries may have a wider application that can be utilized in the near future aside from the packaging. One of the potential applications is in the automotive production due to its properties. The fungi identified grew due to starch used for the development. Future research should be carried out for durability and resistance from fungal growth. Several antifungal and antibacterial agents could be applied to protect from microbial infection while using bioplastics.

Ethical Approval: - No ethical approval in this study

Consent to Participate: - Yes

Consent to Publish: - Yes

Funding: No Source of Funding

Competing Interests: No Competing Interests

Availability of data and materials: All data is available in the manuscript file.

Conflict of Interest: No conflict of interest

Author Contribution- D. Bhawsar conceptualized the study, supervised the experimental design, and finalized the manuscript. A. Jain contributed to methodology development, data validation, and manuscript editing, while S. Chawda assisted in experimental execution and data interpretation. G. Mali supported the identification and characterization of fungal species, and N. Retrekar participated in the literature review, data collection, and preparation of results. K. Patil assisted in formulation studies, graphical representation, and formatting of the manuscript. All authors read and approved the final version of the manuscript.

REFERENCES

1. Chin, W. Ruo Yao, L. Shang-Ming, H. Wei-Song, M. De Guzman, H. Chien-Chieh and L. Kueir-Rarn, T. Chi-Hui, S. Maw-Cherng, Y. Wei-Hua, Y. Jen-Taut, W. Chin-San, T. Chih-Yuan, C. Shih-Hsuan, C. Jui-Preparation and Characterization of Bioplastic-Based Green Renewable Composites from Tapioca with Acetyl Tributyl Citrate as Plasticizer Materials 7, pp. 5617-5632 (2014).
2. De Marco D, Perotti M, Ossi CM, Burioni R, Clementi M, Mancini N. Development and validation of a molecular method for the diagnosis of medically important fungal infections. *New Microbiol.* 2007;30(3):308–12. [PubMed: 17802916].
3. Domenek S., Feuilloley P., Gratraud J., Morel M. H. and Guilbert S. (2004) Biodegradability of wheat gluten based bioplastics, *Chemosphere*, 54, 551-559
4. G. Ismaeil and K. Behzad, Synthesis and Characterization of Biodegradable Starch-based Bioplastics *Iranian Polymer Journal*. 18 (9), 683-69(2009).
5. Gadgile D.P, Chavan A.M. Impact of temperature and relative humidity on development of *Aspergillus flavus* rot of mango fruit. *Sci. Technol.* 2010;3:48–49.
6. Irissin-Mangata J., Bauduin G., Boutevin B. Gontard N., 2001. New plasticizers for wheat gluten films. *European Polym. J.*, 37, 1533-1541
7. Jerez, P. Partal, I. Martinez, C. Gallegos and A. Guerrero, *Biochemical Engineering Journal* 26, 131-138, (2005).
8. L. M. Smits, S. H. D. Hulleman, J. J. G. Van Soest, H. Feil, J. F. G. Vliegthart: The influence of polyols on the molecular organization in starch-based plastics. *Polym. Adv. Technol.* 1999, 10, 570–573.
9. M. A. Araújo, A. Cunha and M. Mota, Enzymatic degradation of starch-based thermoplastic compounds used in protheses: Identification of the degradation products in solution. *Biomaterials*, 25 (2004) 2687–2691.
10. M. L. Sanyang, S. M. Sapuan, M. Jawaaid, M. R. Ishak & J. Sahari (2015): Effect of Plasticizer Type and Concentration on Dynamic Mechanical Properties of Sugar Palm Starch–Based Films, *International Journal of Polymer Analysis and Characterization*; 1-10.
11. Muhammad, A. R. Rashidi, A. Roslan, and S. A. Idris Development of bio based plastic materials for packaging from soybeans waste, *AIP Conference Proceedings* 1885, 020230 (2017).
12. Samson RA, Hoekstra ES, Frisvad JC. Introduction to food-and airborne fungi. *Centraalbureau voor Schimmelcultures (CBS)*; 2004.
13. Stevens ES (2003) What makes green plastics green? *Biocycle* 24:24–27.
14. Thiyam B, Sharma G.D. Isolation and identification of fungi associated with local fruits of Barak Valley, Assam. *Curr. World Environ.* 2013;8(2):319–322.