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R Reddy Nagesh
PG Scholar, Centre for Agricultural Nanotechnology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

V Gomathi, Pon.
Professor (Microbiology), Centre for Agricultural Nanotechnology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Sathya Moorthy
Assistant Professor (Physics), Department of Basic Engineering & Applied Sciences, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

S Thirumalairajan
DBT Ramalingaswami Re-entry Faculty Fellow (NST), Centre for Agricultural Nanotechnology Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

A Ramalakshmi
Associate Professor, (Microbiology), Department of Food Process Engineering, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Corresponding Author:
R Reddy Nagesh
PG Scholar, Centre for Agricultural Nanotechnology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Parthenium-derived nano biodegradable films: A green alternative to plastic packaging

R Reddy Nagesh, V Gomathi, Pon. Sathya Moorthy, S Thirumalairajan, and A Ramalakshmi

Abstract
Fossil fuel plastics disintegrate into tiny pieces known as microplastics, which represent a more significant threat due to easy entry into the digestive system of living species and difficulty in detection. This research aimed to create bioplastic from *Parthenium hysterophorus*, one of the world's most invasive and destructive weeds due to its negative impacts on ecosystems, agriculture, and human health. Using the chlorination and alkaline extraction method cellulose was extracted and then converted to Nanocellulose. Biodegradable plastic sheets were developed by integrating chitosan and Nanocellulose. These bioplastic sheets degrade in 35-45 days under natural circumstances. The decomposition of both chitosan and cellulose can release carbon and nitrogen compounds into the environment. These compounds can contribute to soil fertility and microbial growth. As a result, the bioplastic films made from parthenium and chitosan have the potential to replace plastics made from petroleum.

Keywords: Parthenium, nanocellulose, weed abatement, biodegradable film

Introduction
Fossil fuel-based plastics, including polyethylene, polypropylene, and polyvinyl chloride, have revolutionized industries and daily life due to their versatility, durability, and low cost. However, the unintended consequences of their widespread use are becoming increasingly evident. Even though petroleum-based plastics have many benefits, their extraordinary resilience to biodegradation makes them a serious environmental danger. (C.J. L opez Rocha *et al*., 2020) [1]. Approximately 4% of the world's extracted fossil fuels are used in the manufacturing of petroleum-based plastics. (Lebreton and Andrady, 2019) [17] Plastics from fossil fuels do not easily decompose; instead, they fracture into tiny pieces known as microplastics. Due to their difficult-to-detect qualities and ease of entry into live species' digestive systems, microplastics offer a greater threat. However, certain plastics can undergo recycling, necessitating extra processes such as segregation, transportation, processing, and reprocessing. (Shen *et al*., 2020) [18]. The persistence of these plastics in our ecosystems and the harm they cause to wildlife and human health underline the urgency of finding sustainable alternatives. Thus Plant-based biofilms can be used as sustainable alternatives to conventional plastics. These biofilms can be derived from sources such as starch, cellulose, chitosan, and proteins, helping reduce the environmental impact by offering biodegradability and compostability. (Muneer *et al*., 2021) [7]

Parthenium hysterophorus L. was unintentionally introduced to India by importing its seeds together with PL 480 wheat grain, (Patel, S., 2011) [2] which is the world's most invasive and destructive weed due to its rapid growth, ability to adapt to various environments, and negative impacts on ecosystems, agriculture, and human health. The flowers produce large amounts of lightweight seeds that are easily dispersed by wind, water, animals, and human activity. (Afzal *et al*., 2022) [8]. Pollen from Parthenium flowers is an allergen that causes respiratory, skin, and health issues in susceptible individuals. (Gajanan, G., & Fernandes, 2015) [9] so, Parthenium weed control is a priority for agricultural and environmental authorities, requiring integrated strategies involving mechanical removal, biological control, and cultural practices.

P. hysterophorus is a source of cellulose extraction for the creation of biodegradable materials since it includes 78% holocellulose, 15.8% pentosans, and 17.2% lignin. (Naithani, S. *et al*., 2008) [3] & (Varshney, V. K., & Naithani, S. 2011) [4]. Cellulose is one of the renewable polymers that is widely distributed around the planet (Voicu *et al*., 2016) [5]. Cellulose is a linear homopolymer of β-D-glucopyranose units having long chains joined by (1→4) glycosidic bonds. (Kono, H., Erata, T., & Takai, M. 2003) [19] & (Nishino, T., Matsuda, I., & Hirao, K. 2004) [20]. Cellulose derivatives, such as cellulose acetate and cellulose ethers, are used in various products including films, coatings, textiles, and pharmaceuticals. (Morán, J. I *et al*., 2008) [11] & (Maheswari, C. U *et al*., 2012) [12] Varshney and Naithani conducted a study in which they reported the chemical functionalization of cellulose extracted from Parthenium weed. (Varshney, V. K., & Naithani, S. 2011) [4]. Using the chlorination and alkaline extraction methods, cellulose was extracted from parthenium (Nigam *et al*., 2021) [6].

Chitosan is used as a plasticizer in biofilm preparation which is a biopolymer derived from chitin, having properties like biodegradable, biocompatibility, and antimicrobial, improve the mechanical properties, such as tensile strength and flexibility of biodegradable biofilm. (Zárate-Moreno, J. C *et al*., 2023) [10]. Chitosan-cellulose biofilms are biodegradable materials that have gained attention for their potential to serve as eco-friendly alternatives to conventional plastic film. These biodegradable break down, releasing nutrients like carbon and nitrogen, benefiting nearby plants and organisms. The major priority of this work is producing biodegradable films by extracting cellulose from parthenium weed in the context of waste to wealth. These biofilms have many uses in food, agriculture, medicine, and wastewater treatment.

Materials and Methods

Materials

Parthenium collected from TNAU farmlands. Toluene, sodium hypochlorite, sodium hydroxide pellets, Sulphuric acid, sodium bisulfate, acetone, and acetic acid.

Plant sample collection and treatment

Parthenium hysterophorus weed was collected before the flowering stage. Parthenium was gathered and thoroughly cleaned with water to eliminate all debris. After washing with water, the plant was dried in a hot air oven at 50 °C for drying. Dried biomass was blended to obtain fine powder biomass followed by sieving results in parthenium biomass (Fig. 1) useful for cellulose extraction.

Cellulose Extraction

Cellulose Extraction By Chlorination And Alkaline Method (Nigam *et al.*, 2021) [6]

Using the Soxhlet apparatus, parthenium biomass was dewaxed by treating it with Toluene and Ethanol for 6 hours. (2:1, v/v). (Reddy, K. O *et al*., 2016) [13]

The dewaxed powder was rinsed with distilled water and 90% ethanol. Then it was dried in a hot air oven at 50 degrees Celsius.

It was treated with 3% sulphuric acid (1:50) fiber: liquid ratio at 90 °C for 2 hours with constant stirring for hydrolytic degradation of the hemicellulose content within the material. (Krishna Rao, R. V *et al.*, 2001) [14]. Then rinse three times with distilled water and oven-dried at 50 °C

The sample was treated with 0.7% sodium hypochlorite solution under continuous stirring @ 90 °C for 2 hours (1:50 liquid: fiber). Then it was rinsed once with distilled water.

The sample was then treated with 2% sodium bisulfate at 30 degrees Celsius for 1 hour. This is to extract Holocellulose. After being filtered and cleaned with distilled water, the product was dried in a hot air oven at 50 °C.

Then the sample is subsequently treated with 5% sodium hydroxide for 2 hours at 90 °C with continuous stirring. Then rinsed with distilled water.

Cellulose is extracted by treating the sample with 3% sodium hypochlorite at 90 °C with continuous stirring while maintaining a liquid: fiber ratio of (1:50). The solid residue left after oven drying is cellulose. (Fig. 2).

Extracted cellulose was converted to Nanocellulose by probe sonicator at 50% amplitude for 45 minutes. (Biswal, B. K., & Subramanian, K. S. 2019) [15]

Fig 1: Parthenium Biomass

Fig 2: Extracted Cellulose

Development of Nano Biodegradable film

A 1% Nano Fibrillated Cellulose (NFC) solution was prepared by dissolving 1.0 ml of NFC in 100 ml of water. The mixture was then stirred for one hour at 1000 rpm using a magnetic stirrer.

To create a 2% Chitosan solution, 2 grams of chitosan were dissolved in 100 ml of water. The stirring process continued until the chitosan had completely dissolved, and the stirrer was set at 350 rpm.

For the development of the nanofilm, a film solution was prepared by blending 30 ml of the 2% chitosan solution, 2% NFC solution, and 5 ml of 1% Glycerol. This blending process was carried out for one hour at 1000 rpm. The film solution was poured into a Petri plate, and these plates were left to dry in a hot air oven at 50 °C overnight. Once the films had dried, they were removed from the plates and properly stored.

Fig 3: Nano Biofilm.

Results and Discussion

The parthenium weed threatens agriculture, the environment, and human health in a variety of ways. Its tendency to colonize a variety of ecosystems, as well as its harmful effects on both plant and animal life, make it a difficult invasive species to manage and eradicate. So developing Biodegradable film by extracting Cellulose turns waste into wealth. One of the most important requirements in the packaging business is the biodegradability of the packaging material. The produced biofilm is utilized for soil burial decomposition studies. It shows film degrades within 35-40 days.

Biodegradation by Soil burial method

Pre-weighted bioplastic films (3 × 3 cm) were dried in an oven at 70 °C for 24 h, and buried into the soil at a depth of 10 cm. The possible natural landfill biodegradation was determined by weighing the bioplastic films every 15 days till 45 days. (Krishnamurthy, A., & Amritkumar, P.2019) [16]

No. of Days	Sample 1 (mg)	Sample 2 (mg)	Sample 3 (mg)	Sample 4 (mg)	Sample 5 (mg)	Sample 6 (mg)
0th Day	135	139	212	122	177	118
15th Day	97	89	112	77	125	69
30th Day	68	54	73	43	77	41
45th Day	41	27	56	25	61	21

Fig 4: On 15th day

Fig 5: On 30th day

Conclusion

It may be inferred that parthenium which is an invasive and noxious weed having high cellulose content used in Biodegradable film has good tensile strength, and thermal stability and can be used as a replacement for synthetic plastic or as a mulching sheet in agricultural activities, and this efficient management of parthenium waste leads to a pollution-free environment, and sustainable development.

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