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BIODEGRADABLE PACKAGING FILMS USING AGAR

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ABSTRACT :

The urgent need for sustainable solutions to combat plastic pollution has sparked significant interest in biodegradable polymers. This project focuses on developing biodegradable packaging films using agar, a polysaccharide extracted from red algae. Agar is a renewable, underutilized, and cost-effective resource with good mechanical and physical properties suitable for film formation.

The methodology involved agar extraction, preparation of film-forming solutions, and optimization of composition to achieve desirable flexibility and strength. Additives such as glycerol were incorporated to improve flexibility, and water was used to assist in film formation and crosslinking. Tools like centrifugation and film casting molds were employed to create the films. The produced films were evaluated for mechanical strength, water solubility, and biodegradability.

Although formal quantitative assessments were limited, the preliminary results indicate that agar-based films hold strong potential as sustainable alternatives to conventional plastic packaging.Keywords: Natural, Biodegradability, Tensile Strength, Water Absorption, Sustainable Packaging

1. INTRODUCTION:

The growing global crisis of plastic pollution, with over 350 million tons of plastic waste generated annually, presents severe environmental challenges such as persistent landfill accumulation and marine ecosystem degradation (Ibrahim et al., 2019). Conventional, non-biodegradable plastics—commonly used in packaging—pose long-term threats to the environment, prompting the urgent need for sustainable alternatives.

In aerospace and industrial applications, the demand for lightweight, eco-friendly materials is especially critical, as these materials must meet strict performance requirements while reducing environmental impact during production and disposal (Rhim et al., 2015). Biodegradable polymers derived from renewable resources offer a promising path toward sustainable material solutions, aligning with global environmental goals and supporting India's transition to green technologies.

Agar, a polysaccharide derived from red algae, is an attractive candidate for biodegradable packaging due to its natural film-forming ability, biodegradability, and environmental safety (Kanmani & Rhim, 2014). This study focuses on harnessing agar's properties to develop an efficient and eco-friendly packaging film that can replace conventional plastics.

2. METHODOLOGY

The next phase involves material selection, where **agar powder** is chosen as the primary biopolymer due to its excellent film-forming ability, biodegradability, and commercial availability. **Glycerol** is selected as a plasticizer to enhance the flexibility of the films. These selections are based on biocompatibility, film-forming capacity, mechanical performance, and degradation behavior. No additional additives or crosslinking agents are used in this study.

Following this, the experimental development phase involves synthesizing agar-based bioplastic films. The preparation begins by dissolving agar powder (2–3% w/v) in distilled water and heating the mixture to **90–95°C with continuous stirring** until a clear, viscous solution is formed. Glycerol (20–30% of the agar's weight) is dissolved in a smaller volume of water and gently preheated before being gradually added to the hot agar solution with constant stirring. The combined solution is maintained at **80–90°C for an additional 10–15 minutes** to ensure uniform mixing.

The hot, homogeneous solution is then poured into flat molds or Petri dishes and spread evenly to form thin films of approximately **1–2 mm thickness**. The films are left to dry **at room temperature for 24–48 hours.** No hot air oven or accelerated drying methods are used in this process.

The final films are evaluated for several key properties, including tensile strength, flexibility, water absorption, solubility, transparency, and biodegradation behavior. These tests provide insights into the functional performance of the films and help determine their potential applications in sustainable packaging and other biodegradable product domains.

The final phase focuses on optimization and scale-up. Based on the performance evaluation, the most promising formulations are refined further for consistency, strength, and ease of processing. Strategies are developed for cost-effective and scalable production techniques to facilitate potential commercial use and integration into sustainable packaging industries.

2.2 Experimental Steps

The experimental process began with the direct use of commercially available agar powder as the primary raw material for the preparation of biodegradable packaging films.

Preparation of Film-Forming Solution:
A base solution was prepared using:
- Agar powder (2–3% w/v)
- Glycerol (at 20–30% of the agar's weight) as a plasticizer

Optional formulations included the addition of materials like chitosan or gelatin to improve the mechanical and barrier properties of the films.
To prepare the solution, agar powder was dissolved in 100 mL of distilled water and heated to 90–95°C with continuous stirring until a clear, viscous solution was obtained. Simultaneously, glycerol and any additional additives were dissolved in a smaller volume of water and gently preheated.
The plasticizer mixture was then gradually added to the hot agar solution under constant stirring, and the combined solution was maintained at 80–90°C for an additional 10–15 minutes to ensure uniform blending and proper incorporation of all components.

Film Casting and Drying:
The hot, homogeneous solution was poured into flat molds or Petri dishes and spread evenly to form thin films approximately 1–2 mm thick. The films were then left to dry at room temperature for 24–48 hours.
No hot air oven was used in the drying process.
Once fully dried, the films were carefully peeled off and stored under controlled humidity conditions to maintain their integrity and prevent moisture absorption.

Film Evaluation:
The prepared films were evaluated for the following properties:
- Tensile strength
- Flexibility
- Water absorption
- Solubility
- Transparency
- Biodegradability

These evaluations provided insights into the mechanical performance, water interaction behavior, and environmental sustainability of the agar-based films, demonstrating their potential as biodegradable alternatives to conventional plastic packaging.

3. TOOLS AND TECHNIQUES USED

A variety of basic tools and simple techniques were employed to efficiently prepare and process the biodegradable packaging films. These tools facilitated the preparation of polymer solutions and the formation of consistent-quality films.

3.1 Beakers and Measuring Cylinders:

Beakers and measuring cylinders were used to accurately measure distilled water, agar powder, and glycerol. Precise measurement ensured the correct concentration of each component in the film-forming solution.

3.2 Hot Water Bath:

A hot water bath was used to heat the agar-glycerol solution to the required temperature of 90°C. This indirect heating method provided a controlled and uniform heat source to dissolve the agar without the risk of burning or overheating.

3.3 Glass Plate or Silicone Mold:

Glass plates or silicone molds served as casting surfaces for shaping the hot agar solution into thin films. These flat surfaces allowed the solution to spread evenly, resulting in films of uniform thickness.

3.4 Stirring Rod/Spatula:

Stirring rods or spatulas were used for continuous stirring during the heating process to prevent clumping and ensure a homogeneous solution. They were also used to spread the solution evenly during casting.

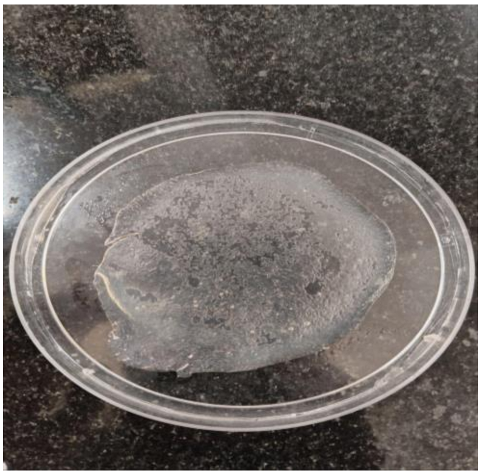
3.5 Room Temperature Drying Setup:

The bioplastic films were dried under ambient room temperature conditions for 24–48 hours. No oven or accelerated drying equipment was used in the process, ensuring natural solvent evaporation.

4. RESULTS:

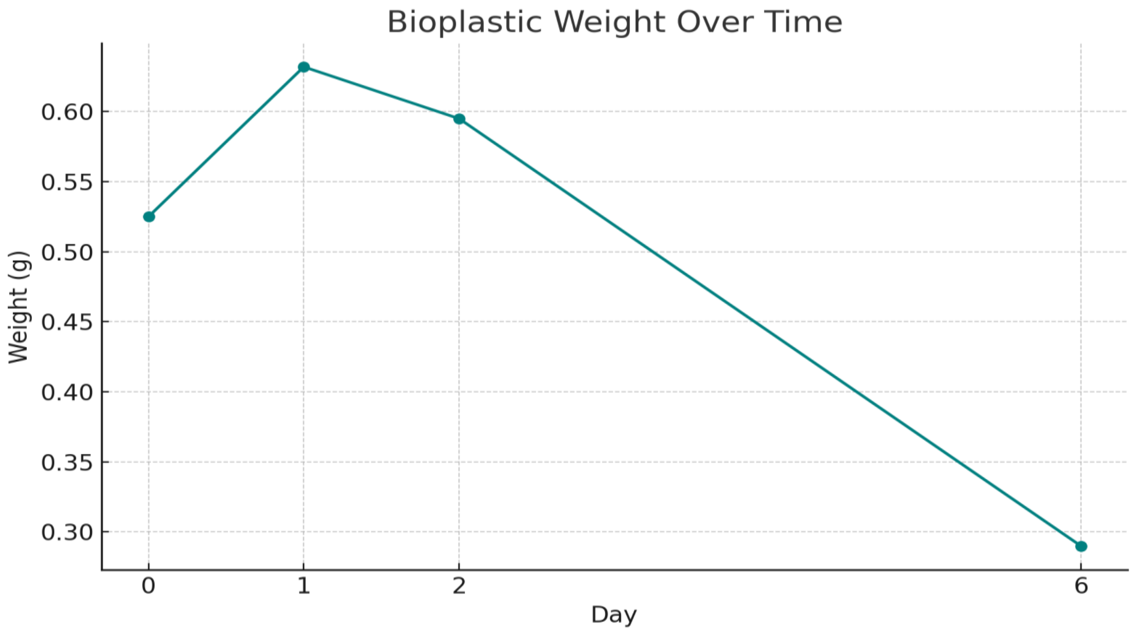
The initial phase of the project focused on the synthesis of bioplastic from agar and its evaluation as a potential material for biodegradable film applications. The resulting bioplastic films exhibited a smooth and uniform surface texture, indicating effective mixing and consistent casting techniques during fabrication.

To assess the suitability of the material, the agar-based bioplastic samples were subjected to a series of tests, including physical property assessments, chemical resistance evaluations, and environmental / biodegradability analyses.

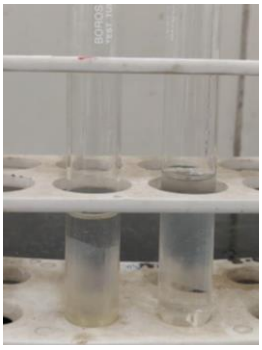
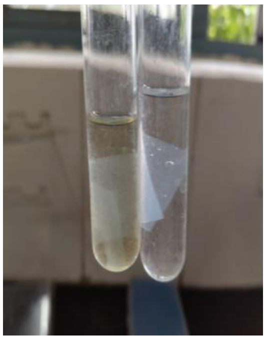
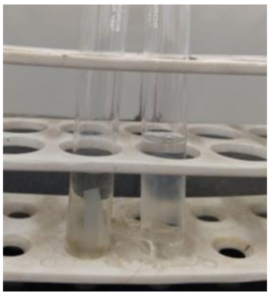


Manual testing of the films revealed moderate flexibility, suggesting that the material could be viable for packaging applications that require pliable yet durable films. The samples also demonstrated reasonable tensile strength, as evidenced by their resistance to tearing under hand-applied pressure.

In the water resistance test, the agar-based bioplastic initially absorbed a noticeable amount of water, with the weight increasing from 0.525 g (dry) to 0.632 g (wet). This uptake demonstrates the material's hydrophilic nature, which is consistent with the intrinsic properties of agar. However, by Day 2, the sample’s weight decreased to 0.595 g, suggesting partial material loss due to solubilization or surface erosion upon prolonged water exposure.Despite these changes, the bioplastic maintained its structural integrity, showing no severe disintegration or deformation. This performance indicates moderate water resistance, making the material potentially suitable for dry goods packaging or short-term applications where limited moisture exposure is expected. However, its solubility under extended contact with water may restrict its usability in high-humidity or wet environments without further modification.



In the chemical resistance test, the bioplastic film was exposed to both acidic and basic environments to evaluate its stability under chemically aggressive conditions. On Day 1, a few distinct reactions were observed on the surfaces in contact with the acid and base, respectively. These included slight discoloration and surface changes, indicating the onset of material interaction.By the following days, visible signs of degradation and weakening of the film structure became apparent, suggesting that the material exhibits only moderate resistance to acidic and alkaline substances. While the film maintained its general shape initially, prolonged exposure appeared to compromise its structural integrity, indicating limited long-term chemical durability.

Day 1	Day 2	Day 6
		

In the environmental/biodegradability test, visual analysis conducted over a period of two days revealed notable degradation of the agar-based bioplastic film. The surface exhibited visible signs of decomposition, including discoloration and fragmentation, particularly at the edges. These observations confirm that the material undergoes biological breakdown under ambient environmental conditions, indicating its biodegradable nature.

Day 1	Day 2	Day 6
		

The agar-based bioplastic demonstrated promising characteristics across multiple evaluation parameters. It showed good film-forming ability, moderate mechanical strength, limited but acceptable water and chemical resistance, and a clear capacity to degrade in natural conditions. These results support its potential use in short-term, environmentally friendly packaging applications, particularly for dry goods. The findings provide a strong basis for further optimization of formulation and performance in future studies

5. DISCUSSION

The study successfully demonstrated the feasibility of synthesizing bioplastic from agar, yielding films with favorable physical characteristics for potential application in biodegradable packaging. The smooth and uniform texture of the produced bioplastic films reflects effective formulation and casting techniques, ensuring consistency in fabrication—an essential factor for scalability in commercial applications.

Flexibility and tensile strength assessments showed that the material is pliable yet sufficiently durable to resist tearing under manual stress. These attributes are vital for packaging applications, especially in contexts where the material must withstand handling and moderate mechanical stress. However, compared to synthetic plastics, the mechanical properties of agar-based bioplastics may still require enhancement through blending with other biopolymers or plasticizers for more demanding uses.

Water resistance testing revealed that while the bioplastic exhibited hydrophilic behavior, typical of agar-based materials, it maintained structural integrity for a limited period. The initial increase in weight due to water absorption, followed by partial weight loss, suggests moderate resistance to water coupled with a degree of solubilization or surface erosion. This finding implies that the bioplastic may be suitable for short-term packaging of dry products but is likely to degrade under prolonged exposure to moisture or in humid environments. Modifications such as incorporating hydrophobic additives or cross-linking agents could enhance water resistance for broader applicability.

The chemical resistance tests further indicated that the agar-based bioplastic is susceptible to degradation in both acidic and basic environments. The onset of discoloration and eventual weakening of the film structure upon extended exposure highlights the limitations of the material in chemically aggressive conditions. This suggests that, in its current form, the bioplastic is best suited for environments with minimal chemical exposure. Further work could involve exploring chemical stabilization strategies or the addition of reinforcing agents to improve long-term durability.

Overall, while the synthesized bioplastic exhibits promising characteristics for eco-friendly packaging, particularly for dry or short-use items, its susceptibility to moisture and chemicals underscores the need for continued material optimization. Future studies should focus on enhancing these properties to expand the practical usability of agar-based bioplastics in real-world applications.

6. CONCLUSION:

The synthesis and evaluation of agar-based bioplastic films demonstrated that agar can serve as a viable raw material for biodegradable packaging solutions. The films exhibited smooth texture, moderate flexibility, and reasonable tensile strength, making them suitable for short-term or dry goods packaging. While the material maintained structural integrity upon initial water and chemical exposure, its hydrophilic nature and limited resistance to acidic and basic environments highlight areas for improvement. Overall, the study confirms the potential of agar-based bioplastic as an eco-friendly alternative to conventional plastics, with future enhancements needed to improve moisture and chemical durability for broader applications.

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