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Green Synthesis and Characterization of Bioplastic by Gelatin and Agar

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Abstract
The rising concern over environmental pollution caused by plastic waste has accelerated the search for sustainable alternatives. Bioplastics, produced from renewable resources, present a promising substitute to conventional petroleum-based plastics by offering biodegradability and reduced ecological impact. This study investigates the green synthesis and characterization of bioplastics prepared from natural biopolymers—gelatin and agar—blended with starch to improve their degradability. Glycerol was incorporated as a plasticizer to enhance flexibility and ensure the material remained fully biodegradable. The bioplastics were characterized using Fourier Transform Infrared Spectroscopy (FTIR) to identify functional groups and analyze their chemical structures. FTIR confirmed the presence of characteristic groups such as O–H, C=O, and C–H, validating the polymeric framework of the synthesized materials. Biodegradability tests were performed through soil burial experiments, which monitored the decomposition of samples over a seven-day period. The results demonstrated that gelatin-based bioplastics exhibited the fastest rate of biodegradation, followed by agar–starch blends. These findings emphasize the potential of gelatin–agar–starch formulations as environmentally friendly materials with promising applications in packaging, biomedical devices, and other industries where sustainability is essential. However, challenges remain in enhancing durability, mechanical strength, and cost-efficiency for large-scale commercialization. Further research is necessary to optimize these parameters and make bioplastics a practical, competitive alternative to petroleum-derived plastics. Overall, the study highlights that bioplastics synthesized from natural polymers can serve as viable substitutes, providing both functionality and ecological benefits while addressing the urgent issue of plastic pollution.
Keywords: *Bioplastics, Biodegradability, Gelatin, Green synthesis, Plastic pollution*

1. Introduction
Plastics have become an integral part of modern life due to their durability, versatility, and cost-effectiveness. However, conventional petroleum-based plastics pose a significant environmental threat due to their non-biodegradability, leading to severe plastic pollution and increased reliance on fossil fuels. Bioplastics, derived from renewable biological sources, have emerged as a promising solution to mitigate these environmental issues. Among various biopolymers, gelatin and agar have demonstrated great potential due to their abundance, biodegradability, and film-forming properties. Gelatin, a protein derived from collagen, is formed when the intramolecular bonds between the three helix chains are broken, resulting in a mixture of proteins and amino acids called gelatin [3]. It forms strong and flexible films but is prone to brittleness without plasticizers. Agar, a polysaccharide extracted from red seaweed, enhances film-forming properties and improves the mechanical strength of bioplastics. The production of bioplastics from gelatin and agar typically involves the use of plasticizers to enhance flexibility and mechanical properties. Glycerol, a commonly used plasticizer, forms hydrogen bonds with biopolymers, increasing their elasticity and reducing brittleness. Water plays a crucial role as a solvent, facilitating the formation of a homogeneous mixture. This study focuses on the production of bioplastics using only gelatin, agar, glycerol, and water ensuring a fully biodegradable and environmentally friendly material without the addition of synthetic components and to assess the

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effectiveness of these bioplastics in reducing environmental impact and analyze their decomposition rates While bioplastics offer a promising pathway to reducing plastic pollution and dependence on fossil fuels, challenges such as production costs, durability, and large-scale manufacturing need to be addressed for their widespread adoption. Despite these challenges, the growing awareness of environmental sustainability is driving increased interest in bioplastics for various applications. This research contributes to the ongoing efforts in developing sustainable materials that balance functionality with environmental responsibility, paving the way for a greener future.

2. Methods

2.1.Materials Required

- Gelatin powder / Agar powder
- Cornstarch (for blends)
- Distilled water
- Glycerol (plasticizer)
- Glass beaker
- Stirring rod
- Heat source (burner)
- Flat surface (Petri dish / glass plate)

2.1.1. Prepare the solution

- Mix polymer (gelatin or agar) with distilled water in a beaker.
- For blends, add cornstarch along with gelatin/agar.
- Add glycerol (1 mL per 100 mL solution) to improve flexibility.
- Stir well until dispersed.

2.1.2. NHeat and dissolve

- Heat the mixture gently while stirring.
- Gelatin dissolves below boiling, agar needs ~85–95°C.
- Starch gelatinizes at ~70–80°C.
- Continue until a smooth, homogenous solution is formed.
- Avoid overheating to prevent degradation.

2.1.3. Adjust consistency (if needed)

- If too thick → add a little distilled water.
- If too thin → add a small amount of gelatin/agar/starch and reheat.
- promising pathway to plastic pollution

2.1.4. Casting the film

- Pour the hot solution onto a Petri dish or glass plate. [1]
- Spread evenly for uniform thickness.

2.1.5. Drying

- Allow to air-dry at room temperature for several hours or overnight.
- Faster drying can be done using a fan or low-temperature dehydrator (<50°C).

2.1.6. Removal of film

- Once completely dry, carefully peel off the bioplastic film.

2.2.Biodegradability

The biodegradability test was done by using soil burial method. A biodegradability test for bioplastics made from gelatin, agar, agar-starch, and gelatin-starch over 7 days, the film began to change physically where cracks were observed on the surface of film associated with a weight loss [7] can be conducted using the following methodology Bioplastic samples (gelatin, agar, agar-starch, and gelatin-starch) are first prepared as thin films by dissolving each biopolymer in water, heating, and pouring into molds to dry, then cut into uniform pieces. The initial weight of each sample (W_0) is measured using a weighing scale. Each sample is then placed in separate containers filled with moist soil, maintaining 60–70% humidity at room temperature (25–30°C) to allow microbial activity. After 7 days, the samples are carefully removed, dried, and weighed again (Wt). The percentage of weight loss is calculated using the formula Weight Loss (%) = $((W_0 – Wt) / W_0) \times 100$, and the biodegradability of the different bioplastics is compared. [2]

2.3.FTIR Spectroscopy

Fourier Transform Infrared Spectroscopy (FTIR) is a powerful analytical technique used to identify and study different materials. It works by passing infrared (IR) light through a sample. Some of the IR light gets absorbed by the sample, and the rest passes through. The absorbed light causes the molecules in the sample to vibrate in specific ways, depending on the types of bonds present. The FTIR instrument measures how much light is absorbed at different wavelengths and produces a graph called an infrared spectrum. This spectrum shows peaks at certain

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points, which correspond to different types of chemical bonds, like O-H (hydroxyl groups), C=O (carbonyl groups), or C-H bonds. By analyzing these peaks, scientists can figure out the composition and structure of a material. FTIR is widely used because it is fast, simple, and does not damage the sample. It is commonly used in chemistry, pharmaceuticals, environmental science, and material testing to identify unknown substances, check the purity of materials, and study chemical reactions. Table 1 shows Sample Weight Analysis

3. Result and Discussion

3.1. Biodegradability Analysis

Table 1 Sample Weight Analysis

Sample	Initial weight (W0)	Final Weight (Wt)	Weight Loss (%)
Gelatin	0.1412	0	100 %
Agar	0.1960	0.1044	46.73%
Gelatin - Starch	0.1286	0	100 %
Agar - Starch	0.2694	0.1180	56.19%

3.2. FTIR Spectroscopy Analysis

Table 2 Sample Particles Analysis

Band	Real Value (Cm-1)	Gelatin (Cm-1)	Agar (Cm-1)	Gelatin Starch (Cm-1)	Agar Starch (Cm-1)
OH	3300-3600	3285	3400	3300	3350
C=O	1600-1800	1652	1650	1650	1640
CH	2800-3000	2850	2882	2825	2900
C-O	1000-1200	1150	1050	1050	1000

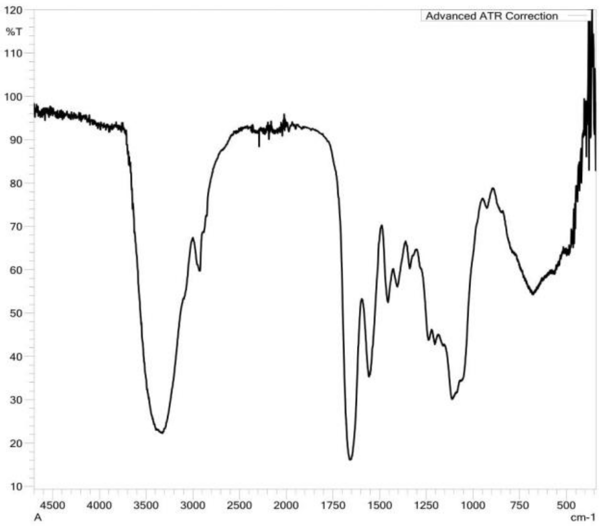

Figure 1 Gelatin

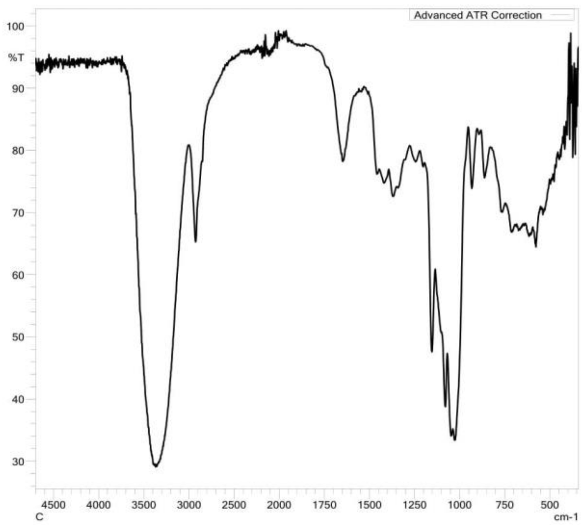

Figure 2 Agar- Starch

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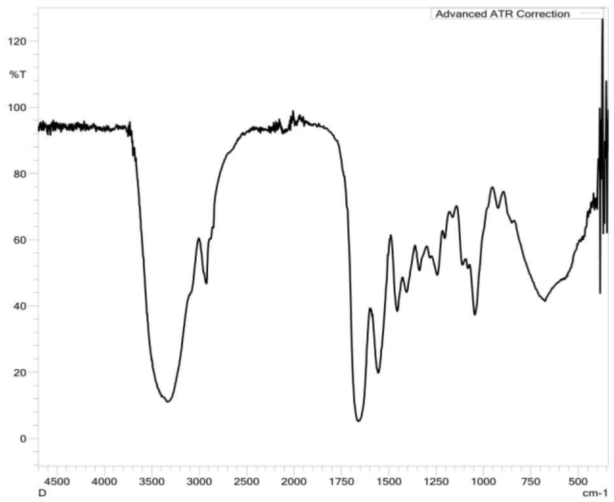

Figure 3 **Gelatin- Starch**

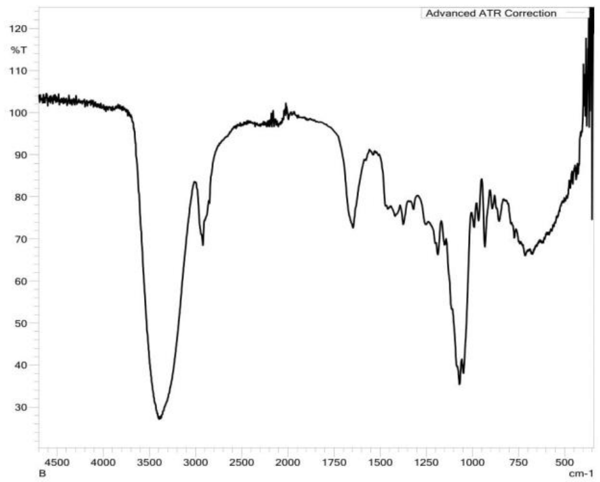

Figure 4 **Agar**

3.3. Discussion

3.3.1. Biodegradability Test

Bioplastics made from gelatin, agar, and their combinations with starch are all biodegradable, but their rates vary. Gelatin-based bioplastics, derived from animal collagen, degrade relatively quickly in compost or soil due to their protein content, which provides nutrients for microorganisms. Agar-based bioplastics, made from red algae, also biodegrade but more slowly because their polysaccharide structure is more resistant to microbial breakdown. Combining gelatin or agar with starch improves biodegradability, as starch serves as an easily digestible food source for microbes. Gelatin-starch bioplastics degrade faster than pure gelatin or agar, while agar-starch bioplastics degrade faster than pure agar but slower than gelatin-starch, with the exact rate depending on the starch-to-agar ratio and environmental conditions such as temperature, humidity, and microbial presence

3.3.2. FTIR Spectroscopy Analysis

The FTIR spectra of gelatin, gelatin-starch, and agar-based bioplastics show characteristic functional groups. Gelatin exhibits a broad peak around 3300–3500 cm^{-1} for O-H stretching, a smaller peak near 2900 cm^{-1} for C-H stretching, and weak signals around 1700–1750 cm^{-1} indicating some carbonyl (C=O) groups. The fingerprint region (1000–1500 cm^{-1}) shows complex vibrations unique to the polymer structure. Gelatin-starch blends display similar O-H and C-H stretches, with a stronger peak near 1700 cm^{-1} representing carbonyl groups, and multiple peaks in the 1000–1500 cm^{-1} region corresponding to C-O or C=C stretching. Agar and agar-starch composites also show broad O-H stretches around 3200–3500 cm^{-1}, C-H stretching near 2900 cm^{-1}, and carbonyl peaks around 1650–1750 cm^{-1}. The fingerprint region (1000–1500 cm^{-1}) contains C-O, C-H, and other bending vibrations. In agar-starch specifically, additional peaks around 600–700 cm^{-1} suggest the presence of C-Cl bonds, indicating possible impurities like PVC. Overall, these FTIR patterns confirm the presence of hydroxyl, carbonyl, and alkane groups in all bioplastic formulations, with minor variations depending on the blend.

Conclusion

This study demonstrates that bioplastics made from gelatin, agar, and their blends with starch are biodegradable and environmentally friendly alternatives to conventional petroleum-based plastics. Gelatin-based bioplastics degrade the fastest due to their high protein content, while agar-based ones degrade more slowly but remain biodegradable. Incorporating starch enhances biodegradability by providing a food source for microorganisms, speeding up the breakdown process. FTIR analysis confirmed the presence of characteristic chemical functional groups, highlighting the natural polymeric nature of these materials. These bioplastics show promising applications in various fields, including packaging, biomedical products, agriculture, eco-friendly consumer goods, and sustainable electronics. With further improvements in durability, water resistance, and cost-effectiveness, gelatin-agar-based bioplastics could become a commercially viable solution, helping to reduce plastic pollution and promote sustainability.

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