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Bioplastic Production from Eggshell Powder

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Abstract

Traditional plastics, mostly derived from petroleum-based sources, contribute significantly to environmental pollution due to their widespread use and inadequate disposal methods. Known for their durability, these plastics can persist for hundreds to thousands of years, leading to the accumulation of plastic waste in natural environments. Over time, they degrade into microplastics, which infiltrate ecosystems and food chains, posing threats to wildlife and human health. Marine plastic pollution is particularly alarming, with millions of tons of plastic waste entering the oceans annually. This results in ingestion, entanglement, and habitat damage for marine life. Furthermore, harmful additives in plastic production can leach into soil and waterways, causing additional ecological harm. To address these issues, bioplastics made from eggshells offer a sustainable and eco-friendly alternative. Eggshells, abundant in calcium carbonate ($CaCO_3$), are biodegradable and cost-effective. This study explores the production of bioplastics by incorporating eggshell powder into a biopolymer matrix composed of natural polymers like starch or chitosan, with plasticizers such as glycerol to enhance flexibility and moldability. The resulting bioplastic exhibits promising mechanical and thermal properties, making it suitable for various applications. By utilizing waste materials and decreasing reliance on petroleum-based plastics, eggshell-based bioplastics provide a viable solution for mitigating the environmental impact of conventional plastics and promoting sustainable material development. This approach not only helps to manage waste material effectively but also contributes to the reduction of plastic pollution. It represents a significant step toward a greener future by offering a practical and sustainable alternative to traditional plastics.

Keywords: Environmental pollution, Microplastics, Bioplastics, Eggshell-based bioplastics.

1. Introduction

The development of bioplastics using eggshells represents a transformative and eco-conscious step forward in addressing the escalating challenge of global plastic waste. Plastic is a synthetic material made primarily from polymers, which are long chains of molecules derived from natural resources like oil, gas, and plant-based materials. It's incredibly versatile and has revolutionized industries by offering lightweight, durable, and cost-effective alternatives to natural materials. From packaging and household items to medical devices and engineering components, plastics are found everywhere. However, while plastics provide countless benefits, their widespread use has raised environmental concerns. Many plastics are nonbiodegradable, leading to pollution and harm to ecosystems when improperly disposed of. This has sparked innovation in creating sustainable and biodegradable plastics, such as bioplastics derived from starch and eggshells, which aim to reduce environmental impact Verlinden, R. A. et al., (2007).

Plastic pollution has become one of the most significant environmental dilemmas of the modern era, with millions of tons of plastic discarded into ecosystems each year. This pervasive waste poses serious threats, including the contamination of soil and water, disruption of ecological balance, harm to marine species, and the relentless pressure on landfill capacity worldwide. As society grapples with the consequences of excessive reliance on nonbiodegradable materials, the urgency for sustainable and viable alternatives has reached a critical point.

Bioplastics have emerged as a pivotal solution to alleviate the environmental burden caused by conventional petroleum-based plastics. Produced from organic, biodegradable materials, these innovative plastics are capable of breaking down naturally, thereby curbing the long-term accumulation of harmful waste. Among the various resources explored for bioplastic production, eggshells offer a distinctive and underappreciated opportunity. Often dismissed as mere food waste, eggshells possess exceptional properties that can be repurposed for the creation of eco-friendly products, underscoring the ingenuity and potential of material science. (Jones & Lee, 2018).

Eggshells primarily consist of calcium carbonate, a natural compound that has long been utilized across industries, including construction, agriculture, and pharmaceuticals. The versatility of this mineral has recently gained attention for its ability to contribute to the production of biodegradable plastics. By converting eggshell waste into useful bioplastics, this 3 innovative process addresses two critical environmental challenges simultaneously: reducing the harmful effects of plastic pollution and managing food waste effectively. Beyond the ecological benefits, this approach serves as an excellent example of resource-efficient waste management. It aligns with the principles of a circular economy, wherein waste materials are reimagined and reintegrated as valuable resources, paving the way for a sustainable and environmentally friendly future. (Smith et al., 2017).

The Problem of Plastic Waste and Food Waste is to fully appreciate the significance of bioplastics derived from eggshells, it is essential to examine the intertwined challenges of plastic and food waste. For decades, petroleum-based plastics have dominated manufacturing industries due to their low production cost, durability, and widespread applicability. While these attributes have made plastics an indispensable part of modern life, they have also come at an alarming environmental cost. Unlike organic materials, traditional plastics degrade at an exceptionally slow rate—taking centuries or even millennia to decompose. Consequently, these plastics accumulate in ecosystems, resulting in long-term ecological damage.

The issue of plastic waste pollution has become a global crisis, with approximately eight million tons of plastic entering oceans annually. Marine organisms often mistake floating plastics for food, leading to ingestion, suffocation, entanglement, and fatal injuries. Furthermore, the improper disposal of plastic waste contributes to land degradation, clogging urban waterways and releasing hazardous chemicals into the soil. Microplastics, which result from the gradual breakdown of larger plastic pieces, infiltrate aquatic environments and food chains, posing serious health risks to both wildlife and humans.

Meanwhile, food waste adds to this environmental challenge, accounting for billions of tons of discarded organic materials each year. Eggshells, a significant byproduct of food preparation and industrial food production, constitute a notable share of this waste. Despite their abundance, eggshells are typically regarded as worthless remnants and are disposed of in landfills or incinerators, contributing to methane emissions and exacerbating climate change. Methane, a potent greenhouse gas, intensifies global warming, adding urgency to the need for effective food waste management. (Jones & Lee, 2018).

The transformation of eggshell waste into bioplastics offers a multifaceted solution. It simultaneously addresses the environmental harm caused by plastic waste while providing a scalable method for repurposing food waste. By leveraging eggshells as raw materials, this 4 process highlights the potential of scientific innovation to create practical and sustainable responses to pressing global challenges.

Composition and Properties of Eggshells, often overlooked as insignificant leftovers, boast a range of unique structural and compositional attributes that make them valuable resources for bioplastic production. The outer shell of an egg predominantly comprises calcium carbonate ($CaCO_3$), which accounts for approximately 94-97% of its total weight. Calcium carbonate is a widely available mineral, commonly employed in industries such as cement production, soil conditioning, and pharmaceutical formulation. Its broad utility and minimal environmental impact position it as an excellent candidate for repurposing in advanced material manufacturing. (Jones & Lee, 2018).

In addition to calcium carbonate, eggshells contain organic proteins, such as collagenand other fibrous substances, that contribute to their strength and durability. These proteins reinforce the structural integrity of the eggshell and could potentially enhance the performance of bioplastic formulations. Moreover, eggshells include trace amounts of minerals like magnesium carbonate and calcium phosphate, which may further enhance the material's properties and versatility.

When processed into fine powder, eggshells become lightweight, non-toxic, and highly compatible with various biodegradable polymers. This characteristic makes eggshell powder a valuable additive in bioplastic production. The inclusion of calcium carbonate in polymer blends improves mechanical properties such as flexibility, durability, and thermal resistance, enabling bioplastics to meet performance standards comparable to conventional plastics. These enhanced qualities make eggshell-based bioplastics suitable for applications in eco-friendly packaging, consumer products, and even specialized medical devices. (Jones & Lee, 2018).

2. MATERIALS AND METHODS:

Bioplastic Production Using Eggshells:

1. Preparation of Eggshell Powder

Collect clean eggshells and rinse thoroughly to remove any remaining egg white or membrane. Allow the shells to air dry completely or oven-dry them at low temperature (around 100°C) for 10–15 minutes. Once dry, grind the eggshells using a mortar and pestle or blender until a fine powder is formed. Set aside.


Fig 1.1Collection of Eggshells Fig 1.2 Processing of Eggshells

2. Mixture of Bioplastic Components

Measure and combine 10 mL of distilled water, 1 tablespoon of cornstarch, 1 teaspoon of glycerol, and 1 tablespoon of eggshell powder in a heat-resistant beaker or saucepan. Stir the mixture continuously to ensure all components are evenly distributed and free from lumps. Verlinden, R. A. et al., (2007).

3. Heating and Thickening Process

Place the mixture over low to medium heat and stir constantly to prevent clumping or burning, allowing the starch to gelatinize and the mixture to thicken gradually. Continue stirring until a thick, gel-like consistency is achieved (around 10–15 minutes). The mixture should appear translucent and pliable.


Fig 1.3 Processing eggshells for Biopolymer production Fig 1.4 Biopolymer production

4. Molding and Drying

Once the desired consistency is reached, carefully pour or spread the bioplastic mixture onto a flat, non-stick surface or mold. Shape or level it to the desired thickness. Allow the bioplastic to air dry for 24–48 hours, depending on humidity and thickness, until fully hardened.

5. Final Observation and Storage

Once dry, gently peel the bioplastic sheet or shape from the surface. Record observations such as flexibility, texture, and appearance. Store the final product in a dry, cool place to maintain its integrity. (Jones & Lee, 2018).

Fig 1.5 Moulding of biopolymers Fig 1.6 Drying and collection

5. RESULTS AND DISCUSSION:

The bioplastic created from a mixture of eggshell powder, cornstarch, glycerol, and distilled water showed promising results in terms of texture and flexibility. The eggshells served as a natural filler, enhancing the strength of the material, while the cornstarch acted as the primary polymer. Glycerol functioned as a plasticizer, contributing to the flexibility and softness of the final product. The resulting bioplastic had a smooth surface and was moldable, demonstrating potential for various practical uses. Overall, the experiment confirmed that eggshells can be effectively reused in bioplastic production, promoting environmental sustainability.

6. DEGRADATION OF BIOPLASTICS:

The degradability of bioplastic was assessed by immersing it in water and placing it in soil to decompose. The process of bioplastic degradation was then monitored.

Fig 2.1 Biodegradability test

S. No	No. of days	Weight
1	Day1	8.23
2	Day2	7.31
3	Day3	5.93
4	Day4	4.68
5	Day5	3.42

Table 2.1 – Biodegradation Rate from Day 1-5

Fig 2.2 Water dissolving test

Fig-2.3 Solubility test in water, acid (Sulphuric acid) and alkali (NaOH solution)

7. Anti-microbial activity:

The anti-microbial activity of the Bioplastics was observed using the control as DMSO (Dimethyl Sulfoxide) and using different concentrations of bioplastics dissolved in Sterile distilled water.

Organism/Zone of inhibition	Control (DMSO) (in cm)	Bioplastic(50µl)(in cm)	Bioplastic(100µl)(in cm)
E. coli	-	1.3	1.2
B. subtilis	-	0.9	1.0
S. aureus	-	0.1	-

Table 2.2 - Anti-microbial activity

Fig 2.3 Anti-microbial activity

Parameters	Result
pH	7.3
Time taken to dissolve in acid (H2SO4)	4 mins
Time taken to dissolve in base (NaOH)	8 mins
Time taken to dissolve in Water	18 mins
Elasticity	5 mins
Moist Heat (90°C)	12 mins
Dry Heat (121°C)	7 mins

Table 2.3 PHYSICAL CHARACTERISTICS OF BIOPLASTICS

Fig 2.4 & 2.5 - Product wrapped with Traditional plastics and Bioplastics

8. DISCUSSION

Creating bioplastics with eggshells presents a fascinating and eco-friendly solution to tackle plastic waste. Bioplastics are sourced from renewable materials, making them a more sustainable option compared to petroleum-based plastics. Utilizing eggshells—commonly discarded as food industry waste—not only reduces waste but also adds functional benefits. Eggshells, composed mainly of calcium carbonate, contribute strength and rigidity to bioplastics. After being ground into fine powder, they are combined with biodegradable substances like cornstarch, which acts as the primary polymer matrix to mimic plastic properties. Glycerol is incorporated as a plasticizer to enhance the flexibility of the final product. This blend of ingredients produces a biodegradable bioplastic capable of breaking down naturally, thereby reducing environmental pollution. The straightforward production process requires minimal tools, making it suitable for smaller-scale manufacturing and educational activities. Nevertheless, bioplastics face certain limitations, such as weaker mechanical strength and lower resistance to moisture compared to conventional plastics. Ongoing research aims to overcome these challenges and improve their market competitiveness. In summary, the production of bioplastics using eggshells, cornstarch, and glycerol is a step towards sustainable materials. This approach efficiently repurposes waste and minimizes the environmental impact of plastic usage.

9. CONCLUSION:

Environmental concerns surrounding traditional petroleum-based plastics have driven efforts to develop biodegradable and sustainable alternatives. Bioplastics derived from natural materials present an effective solution by reducing reliance on fossil fuels and decreasing the accumulation of plastic waste. Eggshells have emerged as a valuable resource in this regard, owing to their high calcium content and abundance as waste from the food industry. Incorporating eggshells into bioplastic production has shown significant promise in enhancing mechanical properties and biodegradability.

The calcium carbonate in eggshells strengthens the bioplastic, making it a viable substitute for conventional synthetic plastics. This approach also supports eco-friendly waste repurposing and contributes to a circular economy. Research on bioplastics incorporating eggshell powder has demonstrated improvements in flexibility, durability, and decomposition rates, along with enhanced tensile strength, water resistance, and material stability. Importantly, these bioplastics exhibit better biodegradability, leading to a reduced environmental impact compared to traditional plastics.

While these advancements are promising, challenges remain in refining the formulations, production processes, and scalability of eggshell-based bioplastics. Further research is essential to improve compatibility with other biopolymers, optimize manufacturing techniques, and enhance product performance. Technological advancements and collaborations within the industry are key to achieving widespread adoption of eggshell-derived bioplastics across various applications.

In summary, utilizing eggshells in bioplastics production offers a sustainable approach to combating plastic pollution while repurposing a readily available waste material. This innovation aligns with global sustainability efforts, promoting resource efficiency and environmentalconservation. Continued development could position eggshell-based bioplastics as a viable replacement for conventional plastics, fostering a greener future.

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