FROM SHELL TO CARRY: THE DEVELOPMENT OF A BIO COMPOSITE BAG USING OYSTER SHELL WASTE

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ABSTRACT

This study aims to develop and evaluate a bio composite bag derived from oyster shell waste as a sustainable alternative to conventional eco bags. By addressing plastic pollution alongside shell waste accumulation, the research employed a product-based quantitative design that combined laboratory experimentation with user evaluation. Oyster shells collected from Samal, Bataan were thoroughly cleaned, dried, pulverized, and processed before being blended with biodegradable components such as agar-agar, glycerin, and vinegar to produce bio-leather samples. These samples were fabricated into prototype materials and systematically compared with regular eco bags using mechanical tests that measured durability, flexibility, and overall material performance. The findings revealed that the oyster-shell-based bio-leather demonstrated promising strength and flexibility, indicating its potential as a functional material. However, the results also showed that further refinement of the formulation and production process is necessary for the material to perform as a fully effective substitute for existing commercial eco bag materials. Anchored in the principles of waste valorization, green chemistry, and life cycle thinking, the study emphasizes the conversion of local waste resources into value-added products. Overall, the research highlights the viability of utilizing oyster shell waste to support sustainable innovation, reduce environmental burdens, and encourage the development of eco-friendly materials that align with responsible production and consumption practices. The study also suggests future work involving long-term usability testing, improved processing techniques, and broader environmental assessments to strengthen material reliability, scalability, and acceptance for potential application in community-based production and sustainable packaging initiatives within local circular economy frameworks and educational contexts.

Keywords: Oyster shell waste, bio-composite bag, bio-leather, sustainable materials, waste valorization, green chemistry, circular economy, eco-friendly packaging, biodegradable materials, product development.

INTRODUCTION

In recent years, solid waste has become one of the most pressing environmental problems globally. Two major contributors are plastic waste, which is non-biodegradable and can persist in the environment for hundreds of years, and shellfish waste, which accumulates in large quantities from aquaculture and seafood industries. Improper disposal of these wastes not only threatens ecosystems and human health but also represents a missed opportunity for resource recovery and sustainable development.

Recent developments in materials science have shown that agricultural and natural waste can be incorporated into biodegradable plastics to create practical and eco-friendly materials. This study focuses on oyster shells, a widely available and often overlooked resource, especially in coastal areas. The goal is to explore their potential as a component in bioplastics that could serve as a sustainable alternative to conventional plastics.

Plastic pollution remains a major global environmental issue. Large amounts of plastic waste accumulate in landfills and water bodies, persisting for centuries and contributing to pollution, harm to marine life, and potential human health risks. Similarly, aquaculture and seafood industries generate vast quantities of oyster shell waste, much of which is discarded along coastlines or in dumps without proper management. Although these wastes are often treated separately, they present an opportunity for an integrated, eco-friendly solution.

This study is based on the principle of turning waste into useful products. Oyster shells, primarily composed of calcium carbonate ($CaCO_3$), may serve as a valuable bio-filler in bioplastics. Unlike conventional plastics, bioplastics are derived from renewable resources and are designed to biodegrade more readily. Incorporating shell powder can improve material strength and environmental performance.

The study is grounded in resource recovery and waste valorization. By using oyster shells as a bio-filler, the research explores how biodegradable polymers can be enhanced while reducing reliance on non-renewable materials. Recent advances have shown that natural fillers can improve both the physical and mechanical properties of bioplastics, supporting environmental sustainability.

Global data indicate that over 5 million metric tons of oyster shells are discarded each year, while plastic production exceeds 390 million tons (UNEP, 2022). Despite prior studies on shell powder in composites, few have fully developed and evaluated a bioplastic product using oyster shells, particularly one that meets basic standards for packaging or other practical applications.

Statement of the Problem

Environmental problems caused by waste accumulation have become increasingly complex, particularly plastic pollution and the improper disposal of shellfish waste. Petroleum-based plastics are highly resistant to decomposition, causing them to persist in the environment for long periods. This leads to the formation of microplastics that contaminate soil and water, threaten wildlife, and pose risks to human health.

At the same time, the growth of aquaculture and seafood processing industries has resulted in large volumes of discarded oyster shells. When poorly managed, these shells are often dumped in landfills or coastal areas, creating sanitation issues and harming marine ecosystems. Despite being organic, oyster shells represent an underutilized resource with potential value.

While previous studies have examined biodegradable plastic alternatives and the use of oyster shell powder as a bio-filler, limited research integrates both issues into a single solution. There is a lack of studies focused on developing bioplastics that combine biodegradable polymers with processed oyster shells while systematically evaluating their physical, mechanical, and biodegradability properties.

This study aims to address the following key research questions:
Can oyster shell waste be effectively processed and integrated with biodegradable polymers to form a bioplastic material?
What are the mechanical properties of bioplastic samples made from oyster shells?

How does the biodegradability of oyster-shell-based bioplastic compare to conventional plastics?
What is the potential of these materials to serve as an eco-friendly alternative for applications such as packaging?

By focusing on these questions, the study seeks to contribute to a growing area of research that attempts to transform waste into a resource, providing a dual solution to the challenges of plastic pollution and oyster shell disposal.

Hypothesis

It is hypothesized that incorporating oyster shell powder into a biodegradable polymer will enhance the bioplastic's mechanical strength and durability. The material is expected to achieve tensile and flexural performance comparable to commercial plastic bags while remaining biodegradable. The calcium carbonate is predicted to act as a reinforcing filler, increasing stiffness and tensile strength without greatly reducing flexibility.

Objectives

To develop and characterize a bioplastic material using oyster shell waste as a primary component combined with biodegradable polymers, here are the specific objectives:

Specific Objectives

To process and prepare oyster shell waste into fine powder suitable for composite applications.
To fabricate bioplastic samples and evaluate their mechanical properties.
To compare the properties of the developed bioplastic/bio leather with conventional petroleum-based plastics and eco bags.
To assess the potential of oyster shell-based bioplastic as an environmentally sustainable material for packaging and related applications.

Significance of the Study

This research holds significance across environmental, industrial, academic, and societal levels. From an environmental perspective, it promotes sustainable waste management and helps reduce plastic pollution. In terms of industry, it encourages the development of eco-friendly products and demonstrates the potential of alternative, sustainable materials. Academically, the study provides valuable insights for future research in science, technology, and material innovation. On a societal level, it raises awareness of environmental challenges and encourages responsible consumption and production practices for a greener future.

Environmental Perspective. From an environmental perspective, this study aims to address issues caused by plastic waste and unmanaged oyster shell waste. By utilizing biodegradable polymers and oyster shell powder, the research supports a sustainable economy where waste materials are reintegrated into the production cycle instead of harming the environment. The development of a biodegradable alternative also reduces dependence on plastic-based materials, which contribute to greenhouse gas emissions and long-term ecological damage.

Industries. Particularly in packaging, manufacturing, and materials science, this study offers potential access to a sustainable alternative to conventional plastics. Such an alternative could lower raw material costs by making use of inexpensive and readily available shell waste while also enhancing a company's ability to meet sustainability goals.

Policy and Waste Management Perspective. The study provides scientific insights that can guide the creation of sustainable waste management programs. Government agencies and environmental organizations can use the findings to encourage recycling and valorization of shellfish waste rather than simple disposal.

Academic and Research Community. This study contributes to existing research on biodegradable composites and bio-fillers by supporting waste-to-resource initiatives. It provides useful data that future researchers can reference and encourages collaboration among fields such as environmental science, materials engineering, and biotechnology.

Society. The study is significant to society as it addresses major issues of pollution and waste management. By promoting a biodegradable material derived from oyster shell waste, it supports the development of environmentally responsible practices. If further developed, this innovation could help reduce plastic waste, protect ecosystems, and promote cleaner living environments.

In conclusion, this research aims to help lessen plastic pollution by creating biodegradable plastic from oyster shells, which are usually treated as waste. It hopes to offer a more eco-friendly option for plastic use and encourage industries to explore sustainable materials. This study may also serve as a helpful reference for future student researchers working on similar environmental problems. Most importantly, it promotes awareness about the importance of reducing waste and finding creative solutions that can benefit both people and the planet.

Scope and Delimitations

This study aims to address the growing need for sustainable alternatives to conventional plastics by developing a biodegradable plastic prototype using oyster shells as the primary material. Specifically, it involves the collection, processing, and laboratory testing of the material's durability and flexibility, with the goal of demonstrating the potential of oyster shells as an eco-friendly option for plastics and eco bags.

However, the scope of the study is limited to small-scale production and does not extend to commercial manufacturing, long-term environmental impact assessment, or detailed cost analysis. Furthermore, the research does not include comparisons with a broad range of commercial plastics and is constrained by the time, budget, and resources available to the student researchers.

Definition of Terms

Polymer. A large molecule made of repeating units called monomers. In this study, the polymer acted as the main base material of the bioplastic film and provided the structure that held all components together.

Bio-filler. A natural material added to improve the strength of a product. A bio-filler derived from waste oyster shells was used to enhance the mechanical properties of the bioplastic.

Calcium Carbonate ($CaCO_3$). A natural compound obtained from oyster shells and used as a reinforcing filler in this study. Calcium carbonate was added to the bioplastic mixture to increase its strength and stiffness.

Tensile Strength. The maximum amount of pulling force a material can withstand before breaking. Tensile strength was measured to determine how strong the bioplastic film was when stretched.
Flexural Strength. The ability of a material to resist bending without breaking. This property was tested to evaluate how well the bioplastic film could withstand bending or applied loads.

Bioplastic Film. A thin and flexible sheet made from renewable biological materials. The bioplastic film was produced using a polymer, glycerin, and calcium carbonate derived from oyster shells as an alternative to conventional plastics.

Glycerin. A substance added to improve flexibility and reduce brittleness. In this study, glycerin acted as a plasticizer, allowing the bioplastic film to bend and stretch more easily.

REVIEW OF RELATED LITERATURE

Bioplastics are emerging as a promising alternative to petroleum based plastics due to their biodegradable structure and reduced ecological impact. Material such as Bivalve shells (oyster shells), that are rich in calcium carbonate are being repurposed as fillers to improve the properties of biodegradable plastics.

Bio-Based Plastics and Fillers
Wu et al (2021) developed composites of polyhydroxyalkanoate with natural fibers and waste oyster shell powder, achieving enhanced thermal stability, antimicrobial functionality, and successful material integration suitable for biodegradable packaging applications.

According to Wang et al. (2023), their composite film demonstrated strong antimicrobial activity two bacteria that can cause infections of the skin and soft tissues, like E.coli and it also achieved a 12.35% increase in tensile strength, a 15.2% reduction in water vapor permeability, and an 80% decrease in UV-B transmittance.

In the Philippines, Lopez and Santiago (2021) demonstrated the feasibility of using eggshell powder as a reinforcing filler in biodegradable plastics. Their study showed that adding eggshell powder improved the material's strength, effectiveness, and compostability. These results highlight the potential of calcium-rich food waste for sustainable bioplastics and suggest similar opportunities for oyster shells. Overall, their work emphasizes how combining waste management with green material science can address pollution while creating valuable products.

Park et al. (2021) examined the synthesis of composite films of ethylene-vinyl acetate (EVA) and linear low-density polyethylene (LLDPE) with calcined oyster shell-derived calcium carbonate ($CaCO_3$) as a filler. They aimed to assess the viability of using calcium-rich marine biowaste in polymer composites, particularly in the Philippine setting where oyster shells are abundant. The results showed that adding biogenic $CaCO_3$ improved mechanical properties like tensile strength and stiffness and provided a cost-effective, eco-friendly alternative for industrial applications. Their study underscores the potential of oyster shells as a green filler while supporting waste valorization and eco-efficient composite development.

To address environmental problems such as plastic pollution and straw burning, Xiao et al. (2020) proposed a diversified waste recycling system and green processing technology. Their study highlighted the conversion of plastic, straw, and oyster shells into both low-cost and high-performance materials suitable for eco-friendly packaging. It demonstrated sustainable approaches for transforming waste into valuable products while tackling multiple environmental challenges.

Garcia et al. (2020) researched the application of sugarcane bagasse and starch in bioplastic production, stating its low cost and biodegradability for packaging applications in the Philippines.

Local Studies on Bioplastics in the Philippines

In the Philippines, Luna et al. (2022) blended banana peel starch with cornstarch to formulate bioplastic films with sufficient tensile strength and good water resistant properties that make them promising for packaging materials.

The study by Austria et al. (2023) explored the viability of starches from cassava, potato, and purple yam as raw materials for bioplastic production. Their findings showed that the most
durable and flexible bioplastics, highlighting the influence of starch source on material performance.

In their comparative study, Garcia & Santos (2020) found that cassava starch based bioplastics degraded more rapidly and yielded only minimal residue compared with commercial plastics that indicates a reduced environmental impact.

Villanueva and Ramos (2021) studied bioplastics derived from seaweed using carrageenan extracted from red algae. Their research demonstrated excellent film-forming capabilities, improved mechanical and thermal properties, and antimicrobial effects, highlighting potential

for eco-friendly packaging.

Similarly, Andao, Aduca, and Jimenez (2020) developed a starch-based bioplastic reinforced with golden apple snail shell chitosan, showing enhanced water resistance and slower degradation compared to unreinforced bioplastics. These studies emphasize the importance of raw material selection and reinforcement in improving environmental and mechanical performance. A local study by the Department of Science and Technology (DOST, 2021) explored sago starch-based bioplastics, noting their industrial potential due to local abundance.

Waste Valorization and Shell-Based Fillers

Recent studies have explored using shell and agricultural waste for sustainable materials. Popović et al. (2023) examined shell waste management to mitigate organic pollution and enhance sustainability, highlighting strategies and challenges in reutilization. Eziwhuo et al. (2023) investigated biodegradable brake pads made from coconut fiber and oyster shells as asbestos alternatives, demonstrating performance comparable to standard pads and reinforcing the concept of waste valorization.

Marine and Ecological Applications

Sakr et. al (2025), shared their viewpoint in their recent conducted study about evaluating the performance and ecosystem functionality of alternative oyster garden structures in residential waterways in Florida, USA. Their study highlighted the idea of a change in the garden, conducted an experiment in a constructed canal system on Sanibel Island, a barrier island. This approach provides a comprehensive view of the structures' viability by documenting their initial success, their response to a major environmental disturbance, and their ability to recover. The addition of this experiment strengthens the study's purpose and objective.

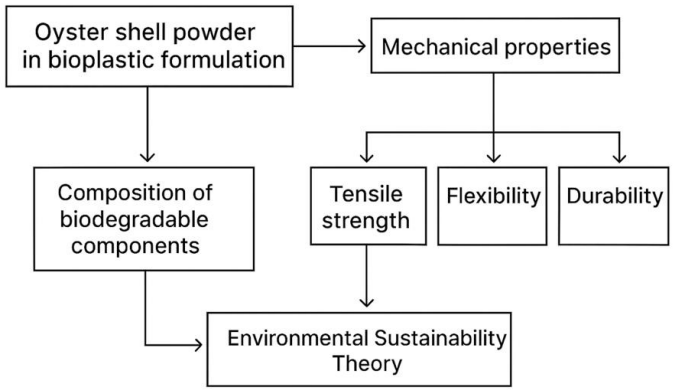
A study concluded by Yang et. al (2024), who examined utilizing recycled pumice and oyster shell waste for cost-effective treatment, to mitigate pollutants and toxicity in swine wastewater. Moreover, in regards to obstacles such inadequate wastewater management leads to excessive metals and organic matter, causing environmental impacts on aquatic and terrestrial ecosystems their research reasserted the need for environmental sustainability. Their study concluded into recycled waste pumice and oyster shells for the cost-effective treatment and reclamation of swine wastewater.

Theoretical Framework

This study is grounded in the Theory of Waste Valorization, which emphasizes transforming waste into higher-value products. Oyster shells, often discarded in coastal areas, are treated as a valuable raw material, promoting resource recovery and sustainable innovation. The research is also guided by the Principles of Green Chemistry, emphasizing renewable feedstocks, safer product design, and waste reduction, aligning with environmentally responsible material development.

Furthermore, the Life Cycle Thinking Framework provides a perspective on environmental impact from sourcing to disposal, ensuring the bioplastic performs effectively while decomposing safely and supporting a circular economy. Together, these frameworks justify the use of oyster shells in biodegradable plastics and guide the study toward innovative and sustainable solutions.

Conceptual Framework



This study is based on the idea that waste materials can be transformed into sustainable, eco-friendly products through scientific innovation. It focuses on using oyster shell waste—rich in calcium carbonate ($CaCO_3$)—as an additive in biodegradable plastic, examining its impact on mechanical properties such as strength, flexibility, and durability. This aligns with the principle of waste valorization, which promotes converting discarded materials into valuable resources.

The framework assumes that varying the proportion of oyster shell powder affects the bioplastic's mechanical characteristics. The study aims to determine the optimal formulation for maximum strength and flexibility while maintaining biodegradability. It also compares the developed material with commercial eco-bags to assess its potential as a sustainable alternative.

Guided by the Environmental Sustainability Theory and the Circular Economy Model, the study emphasizes reducing plastic waste through recycling and the reuse of natural resources. By linking waste recycling, scientific formulation, and product evaluation, it demonstrates how innovation and sustainability can work together to address plastic pollution.

Overall, the framework illustrates the relationship between the independent variables (oyster shell powder ratio and additive composition) and the dependent variables (mechanical properties and biodegradability), showing how sustainable material development can contribute both scientifically and environmentally to reducing plastic waste.

METHODS AND DESIGN

This study uses an experimental design to investigate the development and performance of biodegradable plastic using oyster shell waste. This is an approach to provide an alternative method which enables the appraisal of plastic from oyster shells and observe their effects on the physical, mechanical, and biodegradability properties of the bioplastic.

Experimental design enables controlled testing of hypotheses and comparison between different formulations. Laboratory testing will be used to evaluate mechanical and chemical properties compared to conventional plastics and other bioplastics. The process involves collecting oyster shells, processing them into calcium carbonate, integrating them with biopolymer-forming substances (e.g., starch or polylactic acid), and assessing the resulting material's biodegradability,

tensile strength, and environmental impact.

The focus of this study was on identifying suitable plastic for the waste disposal problem conditions affecting the environment. Based on the domestic wastes of plastic, which need to be non-toxic substances, not producing dioxins and be biodegradable and hydrolysable, we verified marine waste oyster shell plastic (Shu-Yao Tsai, 2021).

STEP	PROCEDURE	FIGURE
Preparation	Crush the oyster shells into powder form by using a hammer to smash or a blender to pulverize.	
	Set up all the necessary ingredients that are needed in making the product.	
Mixing of the ingredients	Mix water (600ml), glycerin (250ml), white vinegar (350ml), agar-agar (75g), and oyster powder (⅛ cup) while the stove is not turned on to insure that there is no clumps of ingredients in the mixture.	
Boiling	Let the mixture simmer for about 1-2 minutes or until the mixture is viscous while mixing.	
Pouring into the mold	Pour the mixture into the mold and let it set for 1-2 minutes before putting the bioplastic mixture into the oven.	
Drying Process	Pour the mixture into the mold and let it set for 1-2 minutes before putting the bioplastic mixture into the oven.	

Formula Testing

Item	Quantity Used
Water	120 ml
Cornstarch	¼ cup or 30 g
Glycerin	1 ½ tbsp or 7.5ml
Coconut oil	1 tbsp or 5 ml
Oyster Shell Powder	¼ cup or 30 g

Table 1. Results of Test 1 – Thick Formula with High Oyster Shell Content (Air-Dried)

In this first test, a large amount of oyster shell powder was added, making the formula thick and heavy. The mixture took a very long time to air dry, and once fully dried, it became brittle and broke easily.

The excess amount of oyster shell powder made the bioplastic too hard and inflexible, which prevented it from forming a stable structure. After four days, mold appeared on the surface, likely caused by the long drying time that allowed moisture to remain trapped inside.This test showed that too much oyster shell powder can make the bioplastic difficult to dry and overly brittle.

Item	Quantity Used
Water	120 ml
Cornstarch	¼ cup or 31g
Glycerin	1 ½ tbsp or 7.5 ml
Coconut oil	1 tbsp or 5 ml
Oyster Shell Powder	¼ cup or 30 g

Table 2. Results of Test 2 – Same Formula as Test 1 (Oven-Dried)

The same mixture was used but oven dried to reduce drying time. While the product dried faster, the overall result was still unsatisfactory. The bioplastic developed cracks and a dry, rough texture like cracked soil. The high oyster shell content continued to make the sample stiff and fragile. Mold also appeared after several days, showing that the faster drying process did not fix the structural issues caused by excessive oyster shell powder. This test confirmed that the quantity of oyster shell powder strongly affects flexibility and overall quality, regardless of drying method.

Item	Quantity Used
Water	5 cups or 1,200 ml
Cornstarch	1/2 cup or 60 g
Glycerin	1/8 cup or 30 ml
Coconut Oil	½ tbsp 7.5ml
Food Coloring	3 drops
Oyster Shell Powder	¼ cup or 30 g

Table 3. Results of Test 3 – Thinner Formula with Coconut Oil (Air-Dried)

This version used less oyster shell powder, producing a thinner and more flexible material. The bioplastic dried properly and held its shape,

showing that the formula was more balanced. However, the thinness of the layer made it less durable and more prone to tearing. The addition of coconut oil improved flexibility but made the product slightly greasy. Despite that, it did not develop mold, suggesting that the moisture content and drying time were well managed. This test showed that lowering the amount of oyster shell powder helps the material stay flexible and stable.

Item	Quantity Used
Water	200 ml
Gelatin	2 tbsp or 16 g
Glycerin	1 tbsp or 15 ml
Food Coloring	2 drops
Oyster Shell Powder	1 tbsp or 8 g

Table 4. Results of Test 4 – Balanced Formula, Air-Dried

The fourth test showed improved performance in molding and drying. The formula was more balanced, and the oyster shell powder helped maintain structure and form. However, after a longer air-drying period, mold started to form, indicating that extended exposure to air and humidity affected the material. While the oyster shell powder contributed to better texture and firmness, this test highlighted the need for a more controlled drying method to prevent contamination and maintain product stability.

Item	Quantity Used
Water	200 ml
Gelatin	2 tbsp or 30 ml
Corn syrup	1 tbsp or 15 ml
Food Coloring	2 drops
Oyster Shell Powder	1 tbsp or 9 g

Table 5. Results of Test 5 – Gelatin Base with Corn Syrup (Air-Dried)

Due to material shortage, this formula used corn syrup as a substitute for glycerin which is the plasticizer and tried gelatin as the base. The mixture did not solidify and remained very liquid, making it clear that the formulation was not compatible. The oyster shell powder did not mix well with gelatin and instead settled, leaving the material unstable. This showed that the mineral filler only works effectively with polymers that can properly bind with it, such as starch or agar, and not gelatin.

Item	Quantity Used
Water	200 ml
Gelatin	2 tbsp or 16 g
Corn syrup	1 tbsp or 15 ml
Vinegar	½ tbsp or 7.5 ml
Food Coloring	2 drops
Oyster Shell Powder	1 tbsp or 8 g

Table 6. Results of Test 6 – Gelatin Formula with Vinegar Added (Air-Dried)

The same formula from Test 5 was used, but vinegar was added to test if it could improve texture or hardening. The vinegar caused minor bubbling and texture changes, but the mixture still failed to solidify. The acetic acid in vinegar likely reacted with the calcium carbonate in the oyster shell powder, releasing carbon dioxide and breaking down the structure further. The result was a weak, watery mixture, showing that acidic additives reduce the effectiveness of oyster shell powder in bioplastic production.

Item	Quantity Used
Water	200ml
Gelatin	2 tbsp or 16 g
Corn syrup	1 tbsp or 15 ml
Vinegar	½ tbsp or 7.5 ml
Coconut Oil	½ tbsp or 7.5 ml
Food Coloring	2 drops
Oyster Shell Powder	1 tbsp or 8 g

Table 7. Results of Test 7 – Gelatin Formula with Coconut Oil Added (Air-Dried)

This test followed the same gelatin-based formula as the previous two but added coconut oil to see if it would affect the texture. The result was still not solid and remained soft, but the surface appeared smoother due to the oil. The coconut oil added slight flexibility but did not solve the issue of poor structure. The oyster shell powder had minimal effect since the gelatin base could not properly support it. This test showed that oil alone cannot fix a weak polymer foundation.

Item	Quantity Used
Water	200ml
Agar-Agar	2 tbsp or 16 g
Corn Syrup	1 ½ tbsp or 22.5 ml
Oyster Shell Powder	3 tbsp or 24 g

Table 8. Results of Test 8 – Agar-Agar Base with Corn Syrup (Oven-Dried)

In this test, agar-agar was used as the base with corn syrup as a plasticizer and oven-dried, resulting in a durable, properly solidified bioplastic; although the heat turned it deep brown and produced a coffee-like or tamarind-like scent, the oyster shell powder reinforced the structure for strength and firmness, while the corn syrup added slight stickiness, demonstrating its effectiveness in agar-based bioplastics.

Item	Quantity Used
Water	200ml
Agar-Agar	2 tbsp or 16 g
Corn Syrup	1 ½ tbsp or 22.5 ml
Vinegar	½ tbsp or 7.5 ml
Oyster Shell Powder	3 tbsp or 24 g

Table 9. Results of Test 9 – Agar Formula with Vinegar & Coconut Oil Added (Oven-Dried)

This test used the same agar-based formula as Test 8 but added vinegar and coconut oil. The oven-dried product remained durable and well-formed but became much stickier due to the coconut oil and vinegar

combination. The acidic vinegar likely reacted with the oyster shell powder, slightly weakening the structure and increasing surface tackiness. Like the previous test, the mixture naturally developed a deep brown color from the oven's heat and gave off a coffee- or tamarind-like smell. Despite the stickiness, this test still produced a strong bioplastic, showing that oyster shell powder remained effective even with minor chemical changes.

Item	Quantity Used
Water	600 ml
White Vinegar	2 tbsp or 30 ml
Glycerin	3 tbsp or 45 ml
Agar-agar	6 tbsp or 32 g
Oyster Shell Powder	⅛ cup or 15 g

Table 10. Results of Test 10 – Final and Most Successful Bio Leather Formula (Oven-Dried)

This test used the same agar-based formula as Test 8 but added vinegar and coconut oil. The oven-dried product remained durable and well-formed but became much stickier due to the coconut oil and vinegar combination. The acidic vinegar likely reacted with the oyster shell powder, slightly weakening the structure and increasing surface tackiness. Like the previous test, the mixture naturally developed a deep brown color from the oven's heat and gave off a coffee or tamarind-like smell. Despite the stickiness, this test still produced a strong bioplastic, showing that oyster shell powder remained effective even with minor chemical changes.

Throughout the series of ten tests, varying formulations were developed to observe how oyster shell powder affects the texture, durability, and overall performance of bioplastic and bio leather. The results showed that the amount of oyster shell powder had a major impact on the product's hardness and flexibility. Mixtures with too much oyster shell powder became rigid, brittle, and took longer to dry, while smaller amounts produced more flexible and workable materials. The tests also revealed that ingredient compatibility plays a key role — gelatin-based mixtures were unstable and failed to solidify, while agar-agar proved to be a more effective base for for forming strong and consistent bioplastics

Drying Method

The drying method influenced both appearance and stability. Air-dried samples often developed mold, while oven drying produced more durable results and naturally turned the material golden to deep brown without food coloring. Respondents noted a coffee- or tamarind-like scent, likely from heat-induced reactions. Overall, the final formula produced a flexible, leather-like material, demonstrating that oyster shell powder can strengthen sustainable bio leather, though further refinement is needed to improve durability and consistency.

Sampling Size

This study uses a purposive sampling method to determine the number of respondents who will evaluate the biodegradable plastic product made from oyster shells. Using Raosoft, an online sample size calculator, the researchers computed the number of respondents needed with a 5% margin of error to ensure the reliability and accuracy of the gathered data. Based on this computation, a total of 76 respondents will be selected to complete a descriptive Likert-scale survey assessing the product's appearance, usability, strength, and environmental potential.

The sample will consist of individuals with basic knowledge or experience relevant to sustainability and environmental issues.

The focus will be on one major potential user group:

- Employees of Colegio de San Juan de Letran–Bataan, especially in the Auxiliary Department, are the major potential users of the biodegradable plastic made from oyster shells because they are part of the institution that fosters its development and share in its vision. Their operations in maintenance, facility services, and logistics involve frequent plastic use for packaging, storage, and daily tasks. Implementing this eco-friendly alternative can significantly reduce non-biodegradable waste generated in these activities, directly supporting the school's environmental goals.

As daily users of plastic in offices, canteens, and events, they can directly benefit from and apply our sustainable alternative, helping reduce the school's environmental footprint. This aligns with Letran's motto, which promotes innovation, collaboration, and, most importantly, sustainability—values that our research embodies. By engaging Letran employees, we not only provide an eco-friendly solution but also strengthen a community-driven effort toward a greener campus.

Sampling Procedure

This study uses purposive sampling to collect oyster shells, which are the main raw material for the bioplastic. The shells will be gathered from nearby seafood restaurants, local wet markets, and vendors especially in the municipality of Samal in Bataan, where oysters are commonly sold and eaten.

The researchers will choose sources that regularly dispose of oyster shells to ensure a steady supply of materials needed for the study. The researchers will coordinate with local seafood vendors to collect discarded oyster shells that are typically thrown away after use. Only shells that meet the following criteria will be used: clean or easily cleanable, not chemically treated or artificially colored, unbroken or minimally damaged, and naturally sourced meaning that they are not from canned or imported oysters. This ensures the shells are safe and suitable for processing.

To maintain ethical and safe practices, the shells will be thoroughly washed, boiled, and dried to remove any remaining organic matter or contaminants before use in the formulation process. This sampling method helps promote sustainability by repurposing waste material, while also making use of resources that are easily accessible and available in the local community. It also supports the environmental goal of the study by reducing food industry waste.

Research Instrument

This product-based quantitative research utilizes both laboratory tools and a survey instrument to aid in the development, evaluation, and assessment of the biodegradable plastic made from oyster shells. The research instruments are divided into two main types:

Production and Testing Tools
These include laboratory equipment such as grinders (for crushing oyster shells), mixing bowls, heat sources (for processing the bioplastic), and molds for shaping. These tools help the researchers create consistent samples and gather accurate data on their performance.

Survey Instrument

To evaluate the final bioplastic product based on public or expert opinion, a Descriptive Likert-scale questionnaire will be used. This survey will be given to selected professionals (such as science teachers, environmental advocates, or industry experts), as well as potential users. The questionnaire will include rating-scale items (e.g., 1–5) to assess the bioplastic's appearance, functionality, sustainability, and overall potential as a plastic alternative. Open-ended questions may also be added to gather suggestions for improvement. The responses will be analyzed to support the product evaluation and guide possible enhancements.

Data Gathering Procedure

The data gathering process will be conducted in two stages: the experimental phase and the evaluation phase, corresponding to the research instruments used.

In the experimental phase, oyster shells will be collected and processed using laboratory tools such as scales, grinders, mixers, heating equipment, and molds. Bioplastic samples will be produced by combining oyster shell powder with other biodegradable materials following a standardized procedure. Key properties—thickness, flexibility, durability, and biodegradability—will be measured using calipers and observation sheets, with all results recorded in data tables for analysis.

In the evaluation phase, completed bioplastic samples will be assessed using a descriptive Likert-scale questionnaire given to science educators, environmental experts, and potential users. Respondents will rate appearance, usability, sustainability, and overall quality, while suggestions will help validate the product's potential and identify improvements.

By combining laboratory testing with user feedback, the study evaluates the bioplastic both scientifically and practically. Data from both phases will be organized in tables and charts for easy analysis, enhancing the reliability and relevance of the results.

Data Analysis

The data collected in this study will be analyzed using both quantitative and descriptive methods to comprehensively evaluate the effectiveness and potential of the biodegradable plastic developed from oyster shells.

For the experimental data, measurements of key physical properties—such as thickness, flexibility, durability, and biodegradability—will be systematically recorded in tables. These results will be analyzed using basic statistical tools, including mean, range, and percentage, to assess the consistency, reliability, and overall performance of the bioplastic samples. Observational notes will also be described in detail to identify visible strengths, weaknesses, and any notable variations among the samples.

Survey data obtained from the Likert-scale questionnaire will be subjected to statistical analysis to determine respondents' overall perceptions of the product. Mean scores and standard deviations will be calculated for criteria including appearance, usability, sustainability, and

overall quality. Open-ended feedback will be categorized and summarized to highlight recurring suggestions, concerns, and recommendations for improvement.

By integrating the findings from laboratory testing with user evaluation, the study aims to provide a thorough and balanced assessment of the bioplastic's technical performance, practical usability, and potential for real-world application, ensuring that both scientific and societal considerations are addressed.

Ethical Consideration
In terms of material sourcing, oyster shells will be collected only from willing vendors, local wet markets, and restaurants that have provided permission. The researchers will ensure that the shells are obtained from food waste that would otherwise be discarded, supporting the environmental goal of waste reduction. No live oysters or marine life will be harmed for the sake of the research. Additionally, proper sanitation will be practiced ensuring the safety of handling organic waste materials, in accordance with health and safety guidelines.

For the experimental phase, all processes will be conducted under the supervision of a research adviser and within school laboratory guidelines to ensure safe handling of equipment and chemicals. The team will use eco-friendly methods as much as possible and dispose of any waste materials responsibly, minimizing harm to the environment.

When conducting the survey or product evaluation, participants will be selected respectfully and ethically. Each respondent will be provided with a clear explanation of the study's purpose, the nature of the questions, and how their feedback will be used. Informed consent will be obtained, either verbally or in written form.

When conducting the survey or product evaluation, participants will be selected respectfully and ethically. Each respondent will be provided with a clear explanation of the study's purpose, the nature of the questions, and how their feedback will be used. Informed consent will be obtained, either verbally or in written form. All participation is voluntary, and participants will have the right to skip questions or withdraw from the activity at any time without penalty. No personally identifiable information will be collected, and all responses will remain anonymous and confidential.

In terms of data management, all collected information—whether quantitative test results or qualitative survey feedback—will be stored securely and used only for academic purposes. Data will not be manipulated or misrepresented, and results will be presented truthfully regardless of whether they support the hypothesis.

Lastly, the researchers commit to upholding academic integrity throughout the project. All sources will be properly cited to avoid plagiarism, and the final output will reflect the team's original work, critical thinking, and honest findings. The entire study will be conducted with transparency, responsibility, and respect for both human and

environmental welfare.

RESULTS

Presentation of Data

This section presents, analyzes, and interprets the data obtained from both experimental testing and survey responses, in accordance with the objectives of the study. The primary focus was on evaluating the bioplastic made from oyster shell powder, particularly in terms of its mechanical strength, thermal stability, water resistance, and biodegradability, in order to determine its potential as an eco-friendly alternative to conventional plastics.

Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used to summarize respondents' evaluations and identify general trends in perceptions. The results indicated that the bioplastic exhibits moderate mechanical and thermal properties, low water

resistance, but high biodegradability, suggesting that the material is environmentally sustainable while requiring further improvements in durability and water resistance.

In addition, Spearman's Rank Correlation was employed to examine the relationships among the material's key properties. The analysis revealed that mechanical, thermal, and water-resistance properties are significantly correlated, whereas biodegradability remains consistently high regardless of changes in other characteristics. This finding indicates that modifications to improve physical performance do not compromise the bioplastic's eco-friendly quality.

All data are presented in organized tables accompanied by detailed discussions, providing a comprehensive understanding of the material's behavior. Through these descriptive and correlational analyses, the study highlights both the strengths and limitations of the bioplastic, demonstrating its overall potential for practical applications and sustainable packaging solutions.

Mechanical Properties

The mechanical properties refer to how strong, flexible, and durable the bioplastic is when pressure or force is applied. Checking this is important because it shows if the oyster-shell-based bioplastic can handle actual use without breaking or deforming easily.

By testing its strength, the researchers can see whether the oyster shell powder makes the material tougher or weaker. This also helps determine how useful it can be for packaging or daily items. Understanding its mechanical performance is important since a stronger and longer-lasting bioplastic means less waste and a more sustainable alternative to regular plastic.

MP1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Good	2	2.6	2.6	2.6
	Average	13	17.1	17.1	19.7
	Poor	32	42.1	42.1	61.8
	Very poor	29	38.2	38.2	100.0
	Total	76	100.0	100.0	

Table 1.1 Frequency and Percentage Distribution for Mechanical Property 1 (Strength & Firmness)

The data shown in Table 1.1 presents the respondents' ratings for MP1, which refers to one aspect of the bioplastic's mechanical performance (such as strength or firmness). The data show that most respondents rated the product as "Poor" (42.1%) and "Very Poor" (38.2%), while only a small number rated it as "Average" or "Good."

This means that the bioplastic was perceived to have weak structural strength and may not withstand pressure or bending effectively. Moreover, the mean score of 4.16 suggests a moderate level of performance, but the high percentage of low ratings indicates that improvements are still needed. Therefore, this result implies that while the oyster shell powder contributes to forming the bioplastic, it is not enough to fully strengthen the material without proper adjustment of its composition or production process.

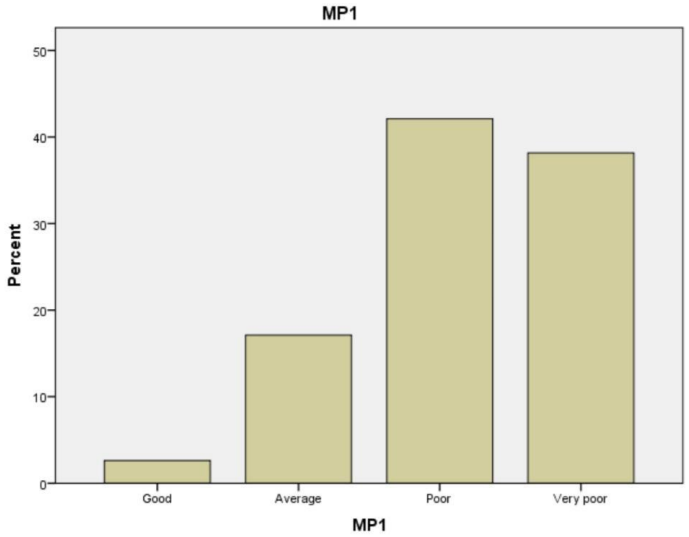


Figure 1. Bar Graph Showing Respondents' Ratings on Mechanical Property 1

As shown in the bar graph, most respondents rated the bioplastic's first mechanical property as "Poor" and "Very Poor." Only a few selected "Average" or "Good," indicating that the bioplastic's strength and resistance to breaking or bending are still limited. In connection with this, the visual data support the results in Table 1.1, where a large majority perceived the material as mechanically weak. Overall, this confirms that while the product can be formed and used, it may not yet be durable enough for heavier or long-term applications.

MP2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Excellent	1	1.3	1.3	1.3
	Good	8	10.5	10.5	11.8
	Average	25	32.9	32.9	44.7
	Poor	25	32.9	32.9	77.6
	Very poor	17	22.4	22.4	100.0
	Total	76	100.0	100.0	

Table 1.2 Frequency and Percentage Distribution for Mechanical Property 2 (Flexibility)

Moving on to MP2, Table 1.2 shows the respondents' evaluation of another measure of the bioplastic's mechanical quality, possibly related to flexibility or resistance to tearing. The findings show that the majority rated it as "Average" (32.9%), "Poor" (32.9%), and "Very Poor" (22.4%), while very few rated it "Good" or "Excellent."
The computed mean of 3.64 confirms that respondents saw the bioplastic's flexibility as only moderate or below average. This suggests that the product can be used but might easily deform or tear when stretched or handled repeatedly. To address this, further optimization in mixing oyster shell powder and biodegradable polymer may help achieve a better balance between flexibility and strength.

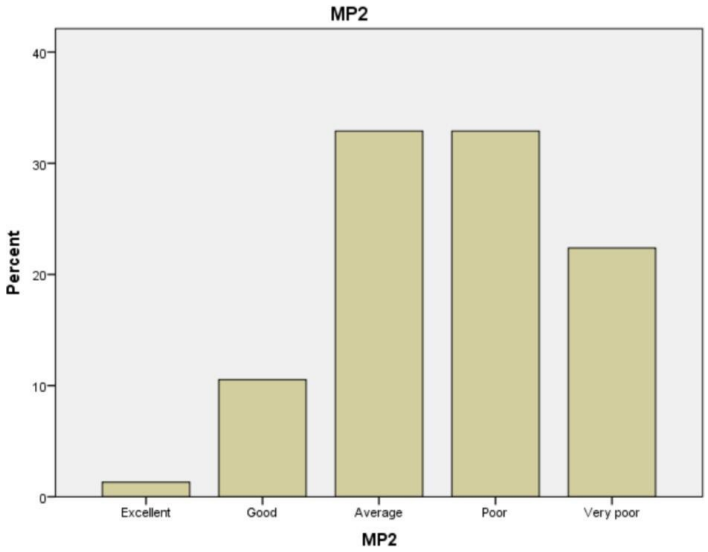


Figure 2. Bar Graph Showing Respondents' Ratings on Mechanical Property 2

Similarly, the bar graph for MP2 illustrates that most respondents rated the material as "Average" and "Poor," with smaller portions marking it as "Very Poor" or "Good." This means the bioplastic shows moderate flexibility but still lacks enough strength to resist tearing or deformation. Likewise, the visual pattern supports Table 1.2, emphasizing that respondents found the material usable but not sturdy. Hence, it can be concluded that although the oyster shell powder helps shape the bioplastic, its formulation needs further adjustment to improve stability.

MP3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Good	2	2.6	2.6	2.6
	Average	13	17.1	17.1	19.7
	Poor	36	47.4	47.4	67.1
	Very poor	25	32.9	32.9	100.0
	Total	76	100.0	100.0	

Table 1.3 Frequency and Percentage Distribution for Mechanical Property 3 (Durability)

Furthermore, Table 1.3 presents the ratings for MP3, another indicator of the material's mechanical durability. Similar to the previous results, most respondents rated it "Poor" (47.4%) and "Very Poor" (32.9%), while only a few rated it higher.

The mean score of 4.11 and mode of 4 indicate that respondents consistently perceived the bioplastic as moderately strong but still not ideal. Thus, while the material can hold its form under limited conditions, it lacks enough durability for heavy or repeated use. Consequently, refining the ratio of oyster shell powder and plastic base may enhance its overall mechanical strength.

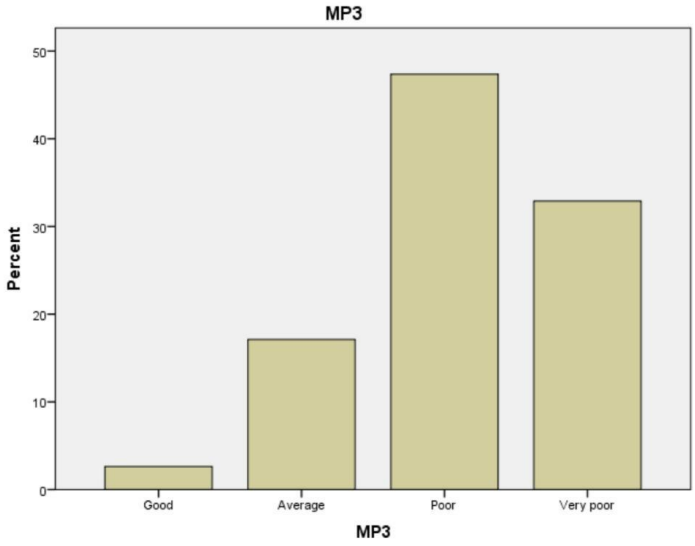


Figure 3. Bar Graph Showing Respondents' Ratings on Mechanical Property 3

The bar graph for MP3 likewise reveals that most respondents rated the material's durability as "Poor" and "Very Poor," confirming that its mechanical performance remains below satisfactory levels.
In comparison with previous results, this pattern is consistent with Table 1.3, which showed that many respondents found the bioplastic lacking in toughness and reliability. Therefore, this visual trend suggests that the material needs improvement to achieve better long-term strength and performance.

Overall, the results show that most participants rated the bioplastic's mechanical properties as "Poor" or "Very Poor," accounting for approximately 60% to 80% of responses. While the mean scores ranged from 3.64 to 4.16, indicating a fair level of performance, the material still demonstrates weak mechanical strength. This suggests that although the bioplastic can be molded and used, it may easily break or deform under force. The slight negative skewness indicates that some samples performed better than others. These findings suggest that oyster shell powder can be incorporated as a component, but the mixture requires further refinement to achieve stronger and more durable mechanical properties.

DISCUSSION

Conclusions

The statistical analysis indicates that the bioplastic made from oyster shell powder has promising potential, though certain properties require improvement. Descriptive results revealed moderate mechanical and thermal performance, meaning the material can be shaped and used but may deform or break under high force or heat. Water resistance was low, making it susceptible to moisture.

Nevertheless, respondents found the bioplastic lightweight, easy to handle, and suitable for packaging dry products. Correlation analysis further showed that enhancing one property, such as mechanical strength, can positively influence others.

Overall, these findings suggest that oyster-shell-based bioplastic can serve as a sustainable alternative for light packaging. With further improvements in strength and moisture resistance, the material could be suitable for broader applications, demonstrating how oyster shell waste can be transformed into a valuable, eco-friendly resource while supporting biodegradable material development.

REFERENCES

Andao, C., Aduca, V. L., & Jimenez, S. M. (2020). *Production of starch-based bioplastic from cassava reinforced with golden apple snail shell chitosan*. https://doi.org/10.13140/RG.2.2.21637.12004

Austria, A. L. G., Barcelona, D. R., Fabros, H. U., Yagyagen, G. A., & Sergio, H. B. Jr. (2023). A comparative study between cassava, potato, and purple yam as a potential bioplastic. *International Journal of Innovative Science and Research Technology, 8*(7). https://doi.org/10.5281/zenodo.8265597

Chong, M. H., Chun, B. C., Chung, Y. C., & Cho, B. G. (2006). Fire-retardant plastic material from oyster-shell powder and recycled polyethylene. *Journal of Applied Polymer Science, 99*(4), 1583–1589. https://doi.org/10.1002/app.22484

Creswell, J. W. (2012). Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research (4th ed.). Pearson Education.

Department of Science and Technology (DOST). (2021). Research on sago starch-based bioplastics for industrial application. *DOST Reports*. https://www.dost.gov.ph

Eziwhuo, S. J., Ogedengbe, T. I., & Ighalo, J. O. (2023). Characterizations of produced biodegradable brake-pads from waste coconut fiber and oyster sea shells as reinforcement materials. *Materials Today: Proceedings, 82*, 126–133. https://doi.org/10.1016/j.matpr.2023.02.314

Garcia, M. D., & Santos, R. P. (2020). Comparative biodegradation study of cassava-based bioplastic and conventional plastic bags. *Asia Pacific Journal of Multidisciplinary Research, 8*(3), 23–30.

Liu, Y., Guo, J., Zheng, X., Tang, K., Lin, L., & Nie, M. (2022). Biofriendly waste shell powders/polylactic acid composites for antibacterial engineering applications. *ACS Omega, 7*(41), 36672–36678. https://doi.org/10.1021/acsomega.2c04779

Lopez, R. T., & Santiago, M. A. (2021). Utilization of eggshell powder in the development of starch-based bioplastics. *Journal of Philippine Materials Research, 9*(1), 17–26.

Luna, F. R., Dizon, A. P., & Tolentino, B. C. (2022). Bioplastic production from banana peel starch and cornstarch: Mechanical and water resistance testing. *Philippine Journal of Agricultural Innovation, 5*(2), 51–59.

Park, K., Sadeghi, K., Thanakkasaranee, S., Park, Y. I., Park, J., Nam, K. H., & Seo, J. (2021). Effects of calcination temperature on morphological and crystallographic properties of oyster shell as biocidal agent. *International Journal of Applied Ceramic Technology, 18*(2), 302–311. https://doi.org/10.1111/ijac.13647

Popović, N. T., Krvavica, M., & Mandić, D. (2023). Crustacean and mollusc shell waste management: Mitigating organic pollution and enhancing sustainability. *Environmental Challenges, 13*, 100812. https://doi.org/10.1016/j.envc.2023.100812

Sakr, J. N., McCarthy, K., & Schmid, S. (2025). Evaluation of alternative oyster garden structures in residential waterways. *Ecological Engineering, 195*, 107091. https://doi.org/10.1016/j.ecoleng.2024.107091

Villanueva, S. G., & Ramos, J. L. (2021). Development of seaweed-based bioplastics using carrageenan from red algae. *Philippine Journal of Coastal Science and Engineering, 6*(1), 38–47.

Wang, H., Liao, Y., Zhu, G., Wang, L., Chen, Z., Li, X., Wang, C., Yu, J., & Song, P. (2025). Development of double-film composite food packaging with UV protection and microbial protection for cherry preservation. *Foods, 14*(13), 2283. https://doi.org/10.3390/foods14132283

Wu, C. S., Wu, D. Y., & Wang, S. S. (2021). Preparation, characterization, and functionality of bio-based polyhydroxyalkanoate and renewable natural fiber with waste oyster shell composites. *Polymer Bulletin, 78*(9), 4817–4834. https://doi.org/10.1007/s00289-020-03341-x

Xiao, D., Yu, Z., Qing, S., Du, S., & Xiao, H. (2020). Development of recycled polylactic acid/oyster shell/biomass waste composite for green packaging materials. *Environmental Science and Pollution Research, 27*(14), 1–29. https://doi.org/10.1007/s11356-020-08956-1