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ARTOCASIA: Evaluating the Effectiveness of Jackfruit Peels as a Primary Material with Taro Root Leaves as a Binder for Marine Oil Spill Booms

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ABSTRACT

This study explores the potential of using carbonized jackfruit peels combined with taro root mucilage as a sustainable alternative for oil spill booms. Addressing the urgent need for environmentally friendly and cost-effective solutions, the research investigates the oil absorption capacity of this composite material. By repurposing agricultural waste, the study provides insights into its hydrophobic and oleophilic properties, making it a viable candidate for small-scale oil spill cleanup operations. Preliminary findings demonstrate its consistent performance across various conditions, showcasing its potential to reduce reliance on synthetic sorbents. While additional research is required for scalability, this approach highlights a promising pathway for marine oil spill management and environmental sustainability.

Keywords: Jackfruit Peels, Taro Root Mucilage, Oil Spill Booms, Eco-friendly Sorbent, Agricultural Waste, Marine Oil Spills, Sustainability.

I. Introduction

The global maritime industry faces an alarming average of over 1.3 large oil spills annually, underscoring the persistent threat these environmental disasters pose to marine ecosystems and coastal communities (International Tanker Owners Pollution Federation Limited, 2024). These incidents disrupt delicate marine life, contaminate shorelines, and challenge cleanup efforts due to their complex dynamics. Notable spills, such as the Deepwater Horizon disaster in 2010, which released approximately 134 million gallons of oil into the Gulf of Mexico, have emphasized the urgent need for effective and sustainable response strategies (National Oceanic and Atmospheric Administration [NOAA], 2024). Despite advancements in technology and response protocols, the search for innovative materials to enhance oil spill management remains critical. Recent studies and global responses to oil spills indicate an increasing exploration of alternative, environmentally friendly materials for spill response.

Oil spills are a pressing global issue, as demonstrated by recent major incidents that underscore the need for innovative solutions in spill management. This includes the 2024 oil spills at DavSam Port in Davao City and the MT Terra Nova spill in Manila Bay, which have shown the persistent environmental and economic impacts of oil contamination (Al Jazeera, 2024; Francisquete, 2024; Macairan, 2024; Dela Cruz, 2024). Additionally, international incidents, such as the 2024 Singapore oil spill, further highlight the need for efficient oil sorbents in various spill scenarios (Ong, 2024; Loi, 2024; Tan, 2024; Koh, 2024; Ahmad, 2024).

In response to these challenges, the use of jackfruit peel as a potential material for oil spill booms has emerged as a viable alternative. Jackfruit peel, which is passively generated by local fruit vendors, presents an opportunity to repurpose a byproduct into a sustainable solution for marine oil spills. Early investigations demonstrate that carbonized peels have oil absorbance capacities. For instance, a study found that orange peel waste, when carbonized, exhibits enhanced oil sorption capabilities due to its oleophilic nature and increased porosity from thermal modification (El Gheriany et al., 2019). This suggests that jackfruit peels, similarly treated, could provide an effective means of oil spill containment.

The study on utilizing jackfruit peels for oceanic oil spill booms promises significant benefits across various sectors. For the Philippine Coast Guard (PCG), this research could provide a breakthrough in improving oil spill response strategies. Conventional containment materials are often expensive and complex to deploy, whereas jackfruit peel offers a more affordable and easily manageable alternative. This advancement could enhance the PCG's ability to respond swiftly and effectively during critical moments, such as the recent MT Terra Nova spill in Manila Bay (Al Jazeera, 2024).

Moreover, the utilization of jackfruit peels for oil spill management aligns with broader environmental sustainability goals by repurposing waste materials. This approach not only mitigates the environmental impact of oil spills but also addresses waste management issues, creating a circular economy where waste products are reused beneficially. As oil spills continue to pose severe environmental threats, innovative and sustainable solutions like the use of jackfruit peels become increasingly vital in protecting marine ecosystems and coastal communities.

II. Materials and Method

A. Preparation and Collection of Materials

Fresh jackfruit (Artocarpus heterophyllus) peels were collected from Agdao market in Davao City. The peels were thoroughly washed to remove dirt and impurities, then sun-dried for 72 hours. After drying, the peels were placed in an enclosed grill and heated to a temperature range of 100-300°C in an inert atmosphere, such as nitrogen gas, to prevent combustion. The material was maintained at this temperature for approximately 8 hours, allowing pyrolysis to occur and convert the organic material into carbon-rich char (Hussein, M. et.al. 2008). After carbonization, the material was allowed to cool to room temperature in the grill before being removed and ground into a fine powder using a mortar and pestle. The powdered jackfruit peel was then stored in airtight containers to prevent moisture absorption.

Additionally, taro roots were peeled and diced into small pieces, then soaked in water. The mixture was heated to 80°C for 1 hour to extract mucilage, followed by filtration to separate the mucilage from the solid residues. The extracted mucilage was concentrated by evaporation and stored under refrigeration (Kubal, K. et. al. 2023). Diesel oil samples were obtained from an industrial supplier, and distilled water, ethanol, and other analytical-grade chemicals were used for sample preparation and testing. Equipment utilized in this study included a mortar and pestle, a filtration setup, and various laboratory glassware.

This process ensured the preparation of carbonized jackfruit peel and taro root mucilage for further experimentation, enhancing the materials' oleophilic properties through carbonization and mucilage extraction.

Image 1: Collection of jackfruit peels at Agdao market.

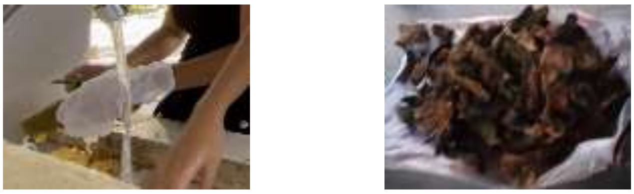


Image 2 & 3: Cleaning and sun-drying of jackfruit peels.

Image 4 & 5: Jackfruit peels carbonization process.

Image 6 & 7: Taro root mucilage extraction.

B. Preparation of Oil Spill Booms

The jackfruit peel powder was mixed with the taro root mucilage in a ratio of 1:1 with both weighing 250 grams. The mixture was shaped into rectangular pad-like booms using a 6x10 silk screen mold and left to air dry for 1 day and was sun dried for 2 days.

Image 8 & 9: Mixing of jackfruit peel powder and taro root mucilage.

Image 10: Molding of jackfruit and taro root mixture.

Image 11: Sun-drying process of oil spill booms.

C. Oil Absorption in Proportion to Size

A ruler was used to measure the size of each pads, which were 6.5 cm in length x 5 cm in width

Formula for surface area:

$$A = \text{Length} \times \text{Width}$$

$$A = 6.5\,\text{cm} \times 5\,\text{cm} = 32.5\,\text{cm}^2$$

From the experiment, the maximum absorption capacity per pad is 13 mL of oil. To determine how much oil is absorbed per square centimeter, we divide the total absorption by the surface area:

$$\text{Absorption per cm}^2 = \frac{\text{Absorbed oil}}{\text{Surface Area}}$$

$$\text{Absorption per cm}^2 = \frac{13\,\text{mL}}{32.5\,\text{cm}^2} = 0.4\,\text{mL/cm}^2$$

The pads had a surface area of 32.5 cm², with an oil absorption rate of 0.4 mL per square centimeter.

D. Oil Absorption Capacity Testing

Oil absorption tests were conducted in a controlled environment. The booms were immersed in diesel oil, and the absorption capacity was determined by measuring the volume of the beaker after a fixed time. Variables such as contact time and amount of seawater and oil, were varied to evaluate their effect on the absorption capacity. The oil absorption capacity was calculated using the formula:

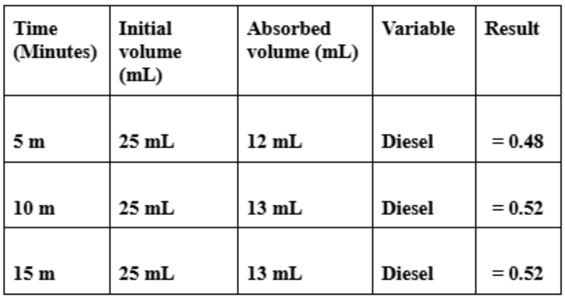
$$\text{Absorption Capacity} = \frac{\text{Absorbed Volume (mL)}}{\text{Initial Volume (mL)}}$$

Risks and Safety

Safety measures were carefully observed throughout the study to ensure the well-being of researchers and the quality of the materials. Proper handling of heated equipment and chemicals was prioritized to prevent burns, spills, or other accidents. The preparation processes were conducted in well-ventilated and designated areas to minimize risks associated with fumes and contamination. Materials were stored securely to maintain their properties and avoid hazards such as combustion or moisture absorption. Additionally, emergency equipment such as fire extinguishers and first-aid kits was readily accessible to address potential incidents. Proper waste disposal and compliance with standard laboratory practices further ensured a safe and controlled environment during the study.

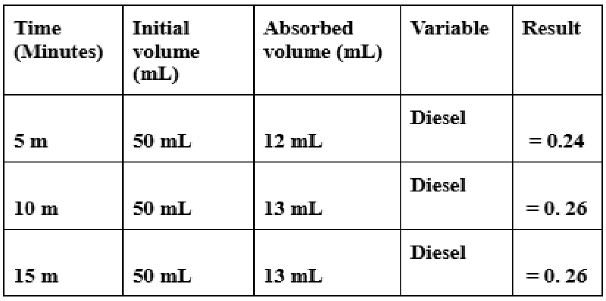
Data Analysis

The researchers utilized descriptive statistics, specifically the mean and standard deviation, to analyze the oil absorption capacity of the sorbent under various conditions. A one-way Analysis of Variance (ANOVA) was used to determine whether significant differences existed between absorption capacities across time intervals and conditions (diesel-only, seawater-only, and mixed environments). The proportional relationship between oil absorption and surface area was also examined, where the sorbent, with a surface area of 32.5 cm², exhibited an absorption rate of 0.4 mL/cm². This analysis highlighted the material's consistency and efficiency across different scenarios.



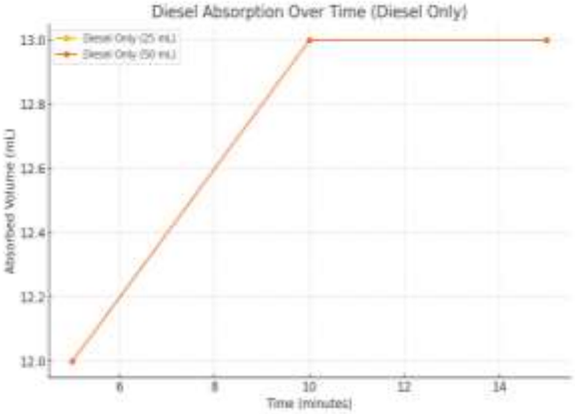
Time (Minutes)	Initial volume (mL)	Absorbed volume (mL)	Variable	Result
5 m	25 mL	12 mL	Diesel	= 0.48
10 m	25 mL	13 mL	Diesel	= 0.52
15 m	25 mL	13 mL	Diesel	= 0.52

Table 1: Diesel Absorption capacity in a 25 ml diesel only environment



Time (Minutes)	Initial volume (mL)	Absorbed volume (mL)	Variable	Result
5 m	50 mL	12 mL	Diesel	= 0.24
10 m	50 mL	13 mL	Diesel	= 0. 26
15 m	50 mL	13 mL	Diesel	= 0. 26

Table 2: Diesel Absorption capacity in a 50 ml diesel only environment



Graph 1: Diesel absorption over time in a diesel only environment

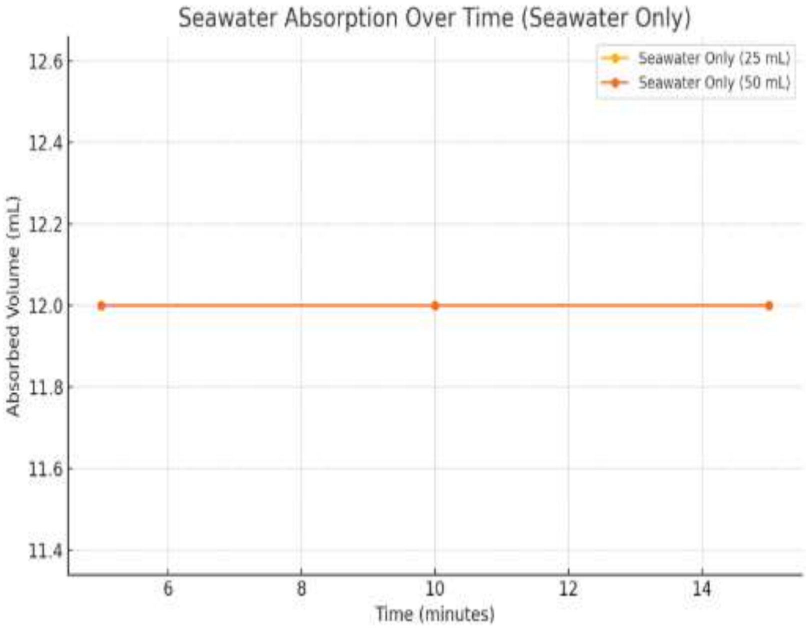
In diesel-only conditions, the sorbent absorbed 12 mL of diesel within the first 5 minutes, increasing to 13 mL at 10 minutes, with no further increase at 15 minutes.

Time (Minutes)	Initial volume (mL)	Absorbed volume (mL)	Variable	Result
5 m	**25 mL**	**12 mL**	**Seawater**	**= 0.48**
10 m	**25 mL**	**12 mL**	**Seawater**	**= 0.48**
15 m	**25 mL**	**12 mL**	**Seawater**	**= 0.48**

Table 3: Seawater absorption in a 25mL seawater only environment

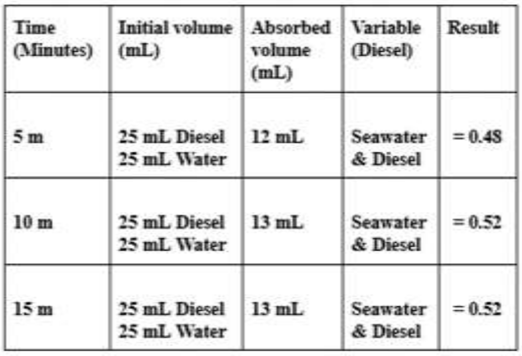
Time (Minutes)	Initial volume (mL)	Absorbed volume (mL)	Variable	Result
5 m	**50 mL**	**12 mL**	**Seawater**	**= 0.24**
10 m	**50 mL**	**12 mL**	**Seawater**	**= 0.24**
15 m	**50 mL**	**12 mL**	**Seawater**	**= 0.24**

Table 4: Seawater absorption in a 50mL seawater only environment



Graph 2: Seawater absorption over time in a seawater only environment

The booms absorbed 12 mL of seawater at all time intervals, reflecting limited variability in water uptake

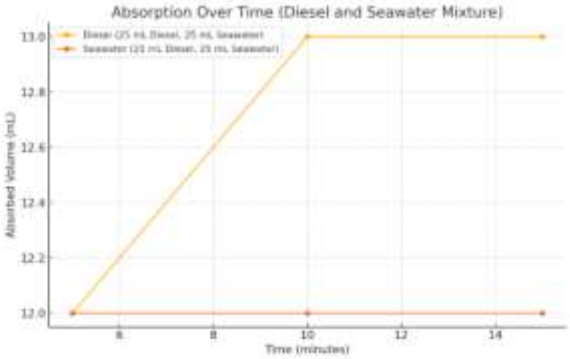


Time (Minutes)	Initial volume (mL)	Absorbed volume (mL)	Variable (Diesel)	Result
5 m	25 mL Diesel 25 mL Water	12 mL	Seawater & Diesel	= 0.48
10 m	25 mL Diesel 25 mL Water	13 mL	Seawater & Diesel	= 0.52
15 m	25 mL Diesel 25 mL Water	13 mL	Seawater & Diesel	= 0.52

Table 5: Diesel absorption in a 50mL seawater and diesel mixed environment

Time (Minutes)	Initial volume (mL)	Absorbed volume (mL)	Variable (Seawater)	Result
5 m	25 mL Diesel 25 mL Water	12 mL	Seawater & Diesel	= 0.48
10 m	25 mL Diesel 25 mL Water	12 mL	Seawater & Diesel	= 0.48
15 m	25 mL Diesel 25 mL Water	12 mL	Seawater & Diesel	= 0.48

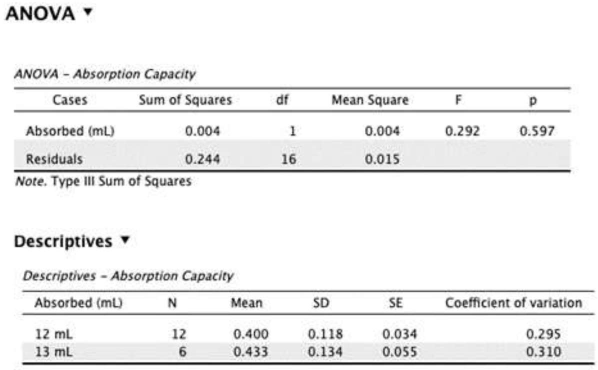
Table 6: Seawater absorption in a 50mL seawater and diesel mixed environment



Graph 3: Comparative absorption over time of diesel and seawater in a diesel and seawater mixture environment

The sorbents maintained the same absorption capacity (13 mL), showcasing its strong oleophilic properties and ability to selectively absorb oil while minimizing water uptake. In seawater-only conditions, the booms absorbed a stable 12 mL of water across all time intervals

Table 7: ANOVA & Descriptive statistics on absorption capacity



ANOVA ▾

ANOVA – Absorption Capacity

Cases	Sum of Squares	df	Mean Square	F	p
Absorbed (mL)	0.004	1	0.004	0.292	0.597
Residuals	0.244	16	0.015		

Note. Type III Sum of Squares

Descriptives ▾

Descriptives – Absorption Capacity

Absorbed (mL)	N	Mean	SD	SE	Coefficient of variation
12 mL	12	0.400	0.118	0.034	0.295
13 mL	6	0.433	0.134	0.055	0.310

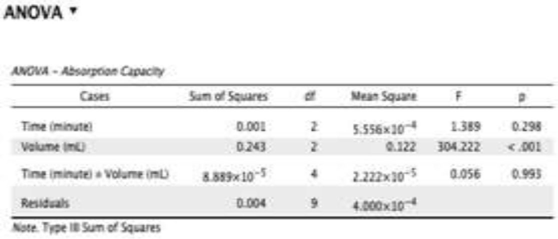
ANOVA Results:

The p-value (0.597) is greater than 0.05, indicating no statistically significant difference between the absorption capacities for 12 mL and 13 mL.

Descriptive Statistics:

- The mean absorption for 12 mL is 0.400, while for 13 mL it is slightly higher at 0.433.
- The variability, as indicated by the standard deviation (SD) and coefficient of variation (CV), is similar for both cases.

The absorption capacities for 12 mL and 13 mL are **not significantly different**, suggesting the pads perform **consistently** under these conditions

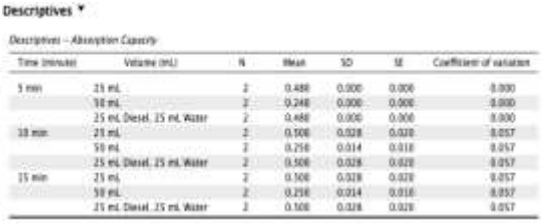


ANOVA ▾

ANOVA – Absorption Capacity

Cases	Sum of Squares	df	Mean Square	F	p
Time (minute)	0.001	2	5.556×10^{-4}	1.389	0.298
Volume (mL)	0.243	2	0.122	304.222	< .001
Time (minute) ✻ Volume (mL)	8.889×10^{-5}	4	2.222×10^{-5}	0.056	0.993
Residuals	0.004	9	4.000×10^{-4}		

Note. Type III Sum of Squares



Descriptives ▾

Descriptives – Absorption Capacity

Time (minute)	Volume (mL)	N	Mean	SD	SE	Coefficient of variation
5 min	25 mL	2	0.480	0.000	0.000	0.000
	50 mL	2	0.240	0.000	0.000	0.000
	25 mL Diesel, 25 mL Water	2	0.480	0.000	0.000	0.000
10 min	25 mL	2	0.500	0.028	0.020	0.057
	50 mL	2	0.250	0.014	0.010	0.057
	25 mL Diesel, 25 mL Water	2	0.500	0.028	0.020	0.057
15 min	25 mL	2	0.500	0.028	0.020	0.057
	50 mL	2	0.250	0.014	0.010	0.057
	25 mL Diesel, 25 mL Water	2	0.500	0.028	0.020	0.057

ANOVA Results:

The p-value (0.993) indicates that there is no statistically significant interaction between time and volume on the absorption capacity, suggesting that both time and volume independently affect the absorption without significantly influencing each other.

Descriptive Statistics:

- For the 5-minute mark, absorption is 0.480 mL for 25 mL of fluid.
- At the 10-minute mark, the absorption is 0.500 mL for the same volume.
- At 15 minutes, absorption stabilizes at 0.500 mL, showing minimal change.

The absorption capacity is consistent across different time intervals and volume conditions, as indicated by the low variability (SD and SE) and the coefficient of variation (which remains low), ensuring reliability in the measurements.

Time does not significantly affect the absorption capacity of the material, while **volume** plays a **more critical** role in determining how much oil is absorbed. The material shows stable and **reliable performance** across different conditions, making it effective for use in practical applications.

III. Results and Discussion

The study, *ARTOCASIA: Evaluating the Possibility of Jackfruit Peels as a Primary Material with Taro Root Leaves as a Binder for Marine Oil Spill Booms*, investigated the oil absorption capacity of a composite material made from carbonized jackfruit peels and taro root mucilage. ANOVA analyses were conducted to evaluate how variables such as volume, time, and environmental conditions influenced the material's performance, while acknowledging the limitations of the small sample size used in this study. The small size of the sample likely restricted the maximum absorption capacity to approximately 13 mL, which was evident in the experimental outcomes.

Statistical Analysis

1. **Analysis of Variance (ANOVA)**

Time (p = 0.973): The absence of statistical significance for time indicates that the sorbent's absorption capacity stabilizes rapidly, irrespective of contact duration. This finding highlights the material's efficiency in reaching saturation within a short timeframe, making it ideal for swift response in oil spill scenarios.

Condition (p = 0.271): No statistically significant differences were observed across the diesel-only, seawater-only, and diesel-seawater conditions. This consistency confirms the material’s uniform performance across various environmental setups, underscoring its versatility in mixed and singular liquid environments.

Volume (p < 0.001): The significant effect of fluid volume on absorption demonstrates the material's predictability in absorbing oil relative to the available fluid. This result validates the sorbent's capacity to consistently handle different liquid volumes, which is essential for controlled applications.

F-value (F = 0.292, p = 0.597): The low F-value suggests minimal variation between the group means for absorbed volumes (12 mL vs. 13 mL). The absence of statistical significance (p = 0.597) further confirms the consistency of the material’s absorption capacity across these two volumes, showcasing its reliability under controlled conditions.

2. **Coefficient of Variation**

The low coefficient of variation (ranging from 0.057 to 0.471) across oil absorption conditions highlights the material's reliability and predictability. While minor variability was observed in diesel-only and mixed environments, this suggests the need for slight operational adjustments to optimize performance. Overall, the material demonstrates dependable absorption behavior across all tested scenarios.

Performance Overview

The carbonized jackfruit peel booms demonstrated consistent and efficient absorption capabilities. In diesel-only conditions, the sorbent absorbed 12 mL of diesel within the first 5 minutes, increasing to 13 mL at 10 minutes, with no further increase at 15 minutes. This rapid saturation is highly favorable for emergency response, enabling swift containment during oil spills.

In diesel-seawater mixtures, the sorbent maintained the same absorption capacity (13 mL), showcasing its strong oleophilic properties and ability to selectively absorb oil while minimizing water uptake. In seawater-only conditions, the booms absorbed a stable 12 mL of water across all time intervals, reflecting their hydrophobic nature. These results demonstrate the material's excellent selectivity and adaptability to real-world marine conditions, where oil and water coexist.

The oil absorption of the carbonized jackfruit peel booms was analyzed in proportion to their size, with each pad measuring 6.5 cm in length and 5 cm in width, resulting in a surface area of 32.5 cm². Given the maximum absorption capacity of 13 mL, the sorbent exhibited an absorption rate of 0.4 mL/cm². This indicates that the material has a strong capacity to absorb oil relative to its size, showcasing its potential for efficient localized oil spill containment. The proportional absorption rate demonstrates that even small quantities of the material can be effective in targeted spill cleanup operations, making it suitable for both small-scale spills and as part of a larger containment strategy.

Opportunities for Optimization

Although the sorbent's absorption capacity (12–13 mL) currently limits its use to small-scale spills, its rapid performance and natural origin highlight significant potential. Refinements in its structure, such as increasing porosity or surface area, could enhance absorption capacity and expand its applications. Additionally, real-world testing in dynamic marine environments—accounting for wave action, temperature, and oil viscosity—will further validate its practical performance and adaptability.

Overall, the carbonized jackfruit peel booms provide a promising, eco-friendly alternative to synthetic sorbents, particularly in scenarios where cost, environmental sustainability, and biodegradability are critical considerations. By repurposing agricultural waste, this material presents a sustainable solution for oil spill cleanup while addressing pressing environmental and economic challenges. With further optimization and testing, it has the potential to play a significant role in oil spill management, particularly in regions with limited access to advanced synthetic materials.

IV. Conclusion and Recommendation

This study has demonstrated that carbonized jackfruit peels, combined with taro root leaves, present a promising and sustainable material for oil spill cleanup. The sorbent exhibited consistent oil absorption, with the ability to absorb 12–13 mL of oil across various conditions and reach rapid saturation within 5 minutes. Its selectivity for oil—absorbing minimal seawater—highlights its effective hydrophobic properties.

In addition, using jackfruit peels, an agricultural by-product, offers significant environmental advantages, including biodegradability and cost-effectiveness. This positions the material as an affordable alternative to synthetic oil sorbents, particularly in resource-limited regions like the Philippines. While the material's absorption capacity is somewhat limited for large-scale spills, it shows great potential for small-scale oil spill response. The low-cost nature of the material and its sustainable production from agricultural waste make it a viable solution for both waste management and oil spill remediation.

However, to further enhance its applicability and effectiveness, additional research is required to improve its absorption capacity, explore reusability, and validate its performance in real-world marine environments. The findings of this study contribute to the growing need for innovative, environmentally friendly solutions in oil spill management. By repurposing agricultural waste, carbonized jackfruit peels offer a promising pathway toward sustainable and effective oil spill response, while reducing the environmental burden posed by synthetic alternatives.

Building on the findings and conclusions of this study, future research should focus on enhancing the sorbent's absorption capacity through structural modifications, such as increasing its porosity or surface area. Investigating methods for reusing the material—such as through mechanical squeezing or thermal desorption—could further improve its cost-effectiveness and practicality. Real-world testing in dynamic marine environments is also essential to evaluate the sorbent's performance under diverse conditions, such as varying temperatures, wave action, and different oil viscosities. These steps will help optimize the material for broader applications, making it an even more viable solution for global oil spill management efforts.

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