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Development and Evaluation of Tensile Strength, Water Resistance, and Biodegradability of Bioplastic using Mermaid's Fan (*Padina pavonica)* Seaweed and Extracted Cellulose from Coconut (*Cocos nucifera)* Lumber Sawdusts

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Abstract— *Plastic pollution has increased demand for bioplastic alternatives. This study developed bioplastic from Mermaid's fan seaweed alginate and cellulose extracted from coconut lumber sawdust. Bioplastics were produced through alginate extraction, cellulose isolation, and material testing, with data analyzed using one-way ANOVA at 0%, 35%, and 70% cellulose concentrations. Results showed no statistically significant differences in tensile strength and water resistance among treatments (p > 0.05). However, water degradation differed significantly (p < 0.05), with the 35% cellulose formulation exhibiting the highest mass loss and fastest degradation. These findings indicate cellulose mainly affects degradation behavior. Therefore, Mermaid's fan-based bioplastic shows eco-friendly potential as an alternative to conventional plastics.*

Keywords— ***Bioplastic, Cellulose, Padina pavonica, Tensile strength, Water Degradation, Water resistance***

I. INTRODUCTION

[1] Plastic pollution has become a serious environmental problem due to the continuous production and improper disposal of petroleum-based plastics. Millions in tons of plastic waste enter marine environments annually, threatening biodiversity, ecosystems, and human health. [2-3] In the Philippines, microplastic contamination has been reported in Laguna de Bay, while coastal ecosystems such as Pujada Bay in Davao Oriental continue to experience increasing plastic accumulation. These environmental concerns highlight the urgent need for biodegradable and sustainable alternatives to conventional plastics.

[4] Previous studies have shown that seaweeds are promising raw materials for bioplastic production because of their polysaccharide content, particularly alginate, which has film-forming and biodegradable properties. The brown seaweed *Padina pavonica* has been identified as a potential source of alginate for sustainable applications. [5] Meanwhile, cellulose derived from plant materials has been recognized for enhancing the mechanical properties of bioplastics, including tensile strength and structural stability. In particular, cellulose extracted from *Cocos nucifera* lumber contains high cellulose content and is suitable as a reinforcing material. However, limited research has examined the combined use of Mermaid's

Fan seaweed and coconut lumber-derived cellulose in developing bioplastics and evaluating on how varying cellulose concentrations influence tensile strength, water resistance, and degradation.

This study aimed to develop a biodegradable bioplastic using alginate extracted from *Padina pavonica* and cellulose extracted from *Cocos nucifera* lumber sawdust. Specifically, the objectives of the study were to: (1) determine whether varying cellulose concentrations (0%, 35%, and 70%) significantly affect tensile strength; (2) evaluate the effect of cellulose concentration on water resistance through mass gain testing; and (3) assess the effect of cellulose concentration on degradation rate through mass loss analysis.

The contribution of this paper lies in providing experimental evidence on the reinforcing effect of coconut lumber cellulose in seaweed-based bioplastic and identifying which material properties are significantly influenced by cellulose concentration. The findings contribute to the development of locally sourced, environmentally sustainable bioplastic alternatives.

1.1 Characteristics of Mermaid's Fan (*Padina pavonica*)

[6] *Padina pavonica*, also referred to as Mermaid's Fan, is a type of brown seaweed characterized by its calcified fronds in the shape of a fan with concentric bands and a lightly mineralized surface texture from calcium carbonate deposits. These characteristics result in the rigidity of the seaweed. Mermaid's Fan is usually found in shallow waters and on coral reefs in tropical and temperate ocean environments, providing food sources and breeding places for different marine life. [7] However, the occurrence of massive quantities of the seaweed on coastlines has resulted in environmental concerns because the decomposing seaweed releases toxic gases such as hydrogen sulfide and ammonia. [8] Massive quantities of the seaweed have also been observed in the Caribbean region, Central America, North America, and Africa. As a result, the governments in these regions are working hard to manage the seaweed.

1.2 Characteristics of cellulose from coconut *(Cocos nucifera)* lumber

[22] Coconut fiber is composed of approximately 67% holocellulose and 25% lignin, values comparable to those of hardwoods, making it a promising source of cellulose for industrial applications. [22] Its most common derivative, cellulose acetate, exhibits excellent transparency, tensile strength, and thermal stability, which supports its widespread use in food packaging, textiles, cigarette filters, and fashion accessories. [23] Furthermore, a study demonstrated that increasing hydrogen peroxide concentration and extending bleaching time significantly improved cellulose quality, with the optimal treatment being 40% hydrogen peroxide for 120 minutes, resulting in high-purity, highly white cellulose with low hemicellulose and lignin content, suitable for bioplastic production, including blends with Sargassum spp. to enhance durability and flexibility.

1.3 Characteristics of cellulose derived from sawdust in bioplastics

[9] Sawdust is a wood-processing byproduct rich in cellulose, hemicellulose, and lignin, with cellulose valued for its strength, renewability, and wide applications. [10] As a sustainable and accessible material, sawdust provides an eco-friendly alternative to synthetic polymers through cellulose extraction. [11] Additionally, cellulose fibers enhance the tensile strength, rigidity, impact resistance, and durability of bioplastics, making them suitable for packaging and structural applications.

1.4 Sargassum -based bioplastic specifically Mermaid's Fan (*Padina pavonica*)

[12] Bioplastics from Mermaid's Fan contain alginate and other polysaccharides used in the production of biodegradable polymers. [13] These are more environmentally friendly than petroleum-based polymers. Research also proves the addition of biodegradable additives improves the mechanical properties and durability of the seaweed-based bioplastics. [14] Mermaid's Fan also shows promising results in the yield of alginate and its positive mechanical properties, achieving a tensile strength of 2.34 MPa and 24.02% elongation. These characteristics are promising for the production of an eco-friendly biodegradable plastic.

1.5 Mechanical and biodegradation properties of seaweed-based bioplastic

[15] Seaweed-based bioplastics exhibit enhanced tensile strength, flexibility, and barrier properties against water vapor and oxygen, making them ideal for packaging, while also demonstrating rapid composting biodegradability as a sustainable option. [16] Their mechanical performance, thermal stability, water resistance, and biodegradability can be further improved using additives such as glycerol, starch, cellulose, and carrageenan, allowing tailored properties for eco-friendly packaging applications. [17] Additionally, alginate-based seaweed bioplastic materials incorporating invert sugar and glycerol display better flexibility and strength, allowing for full biodegradation within days and reducing environmental harm compared with conventional disposing methods.

II. MATERIALS AND METHODS

This study used a quantitative experimental research design to identify the precise effect on key characteristics of bioplastics. Before application, seaweed was harvested, dried, cleaned, and processed uniformly according to standard practices, ensuring reliable and reproducible results There were two sites that the researchers visited. The first research site was Dahican–Bobon Road shoreline, City of Mati, Davao Oriental, where Mermaid's Fan seaweed was collected as the primary raw material. The second site was the Science Laboratory of Immaculate Heart of Mary Academy (IHMA), City of Mati, Davao Oriental, where the collected seaweed was processed and developed into bioplastic. The same laboratory also served as the testing ground for evaluating the produced bioplastic in terms of biodegradability, water resistance, and tensile strength. Lastly, the manuscript were also finished in the same instituition.

2.1 Collection and cleaning of *Padina pavonica* Seaweed

Fig.1. Mermaid's Fan (Padina pavonica)

Fresh Mermaid's Fan seaweed was collected from Bangunay Beach. It is collected fresh and it was thoroughly washed with tap water to remove dirt, sand, salt, and other impurities. After soaking, the seaweed was drained and dried either through air drying, under sunlight, or using an oven at 50°C until fully dehydrated, once dried the seaweed was cut into small pieces.

2.2 Extraction of sodium alginate from *Padina pavonica*

To extract sodium alginate, the dried seaweed was mixed with a 2–3% sodium carbonate solution using a typical weight-to-volume ratio of 1:2. This mixture was heated between 60°C and 80°C for 10 minutes while being continuously stirred to dissolve the alginate. After extraction, the mixture was filtered using filter paper to remove the solid residue, leaving behind a brownish liquid rich in sodium alginate.

2.3 Extraction of cellulose from coconut lumber sawdust

The dried sawdust from Coconut Lumber was first boiled in a sodium hydroxide (NaOH) solution to remove lignin and hemicellulose. This process helped isolate the cellulose content. After boiling, it was then filtered to collect the solid residue and washed to remove remaining chemicals

2.4 Combination of coconut lumber sawdust-derived cellulose and *Padina pavonica* seaweed

The dried powder, which was the alginate extracted from Mermaid's Fan seaweed, was mixed in 100 mL of distilled water. The cellulose from Coconut Lumber sawdust was also added. While stirring, glycerol (30% of the total polymer weight) was added to improve flexibility. The mixture was stirred continuously until everything was smooth and well combined, forming a ready-to-cast bioplastic solution.

2.5 Molding and drying

Once the bioplastic mixture was prepared, it was carefully poured into a clean, flat mold or tray to form a thin film, similar to conventional packaging plastic, with dimensions of 6 cm × 5 cm. The surface was then leveled to ensure uniform thickness, typically maintained within the range of 0.1–0.25 mm.

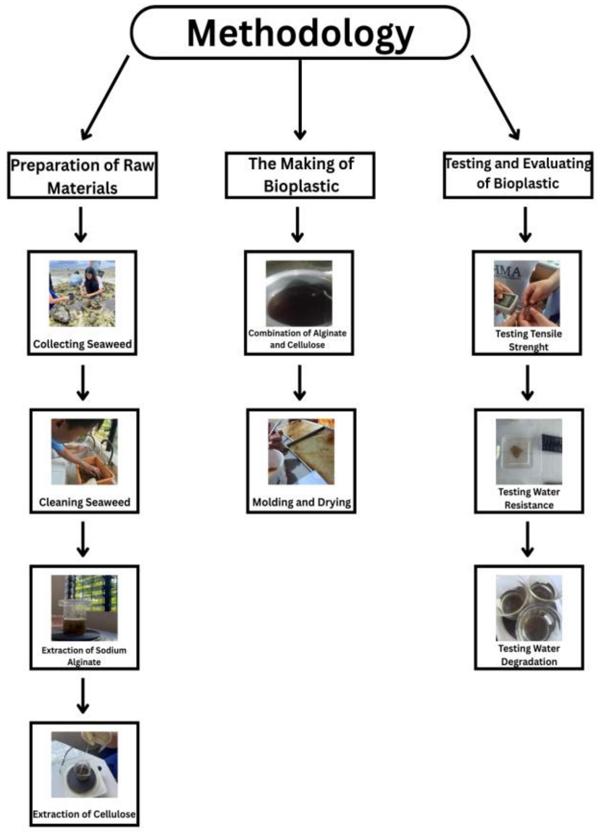

Fig.2. Summary of Methods

2.6 Testing for tensile strength

In order to determine the tensile strength of the developed bioplastic, a force gauge was used. The cut bioplastic was prepared and tested using a force gauge. Each specimen was securely clamped onto the force gauge, and a steadily increasing tensile force was applied until the material fractured, the maximum force at break was recorded for each sample.

2.7 Testing of bioplastic's water resistance

Water resistance was evaluated following the ASTM D570 method. The bioplastic samples were dried and weighed prior to testing, then fully immersed in separate containers containing 200 mL of distilled water at room temperature with a time interval of 2, 4, 6, 8 minutes. Each bioplastic sample was 2 grams.

2.8 Testing of bioplastic's degradation

For biodegradability testing, a seawater immersion test was conducted. The bioplastic samples were dried, and their initial weight (W_0) was recorded prior to testing. Each sample was immersed in a beaker containing 100 mL of seawater at room temperature for 15 minutes, and every sample weighed 1 gram.

III. RESULTS

3.1 The bioplastic performance profile

The samples were analyzed based on tensile strength, water resistance, and biodegradability using experimental testing procedures. Tables 1, 2, and 3 present the summarized results.

Table 1. Tensile Strength of Bioplastic Samples

Cellulose Concentration	***Number of Trials***	***Mean Tensile Strength (MPa)***
0% Cellulose	3	4.97
35% Cellulose	3	8.87
70% Cellulose	3	6.50
Total	***9***	-

Most of the samples showed improved tensile strength with the addition of cellulose. The 35% cellulose concentration recorded the highest mean tensile strength. However, statistical testing indicated no significant difference ($p > 0.05$).

Table 2. Water Resistance Test Results

Cellulose Concentration	***Mean Mass Gain (g)***	***Interpretation***
0% Cellulose	2.87	Moderate Absorption
35% Cellulose	3.10	High Absorption
70% Cellulose	2.73	Low Absorption

The 70% cellulose sample demonstrated better water resistance based on lower mass gain values. No significant difference was observed among treatments ($p > 0.05$).

Table 3. Degradation Test Results

Cellulose Concentration	***Mean Mass Loss (g)***	***Interpretation***
0% Cellulose	0.17	Moderate Degradation
35% Cellulose	0.33	Fast Degradation
70% Cellulose	0.07	Slow Degradation

The 35% cellulose formulation degraded the fastest among treatments. Statistical analysis confirmed a significant difference in degradation ($p < 0.05$).

Most of the bioplastic samples demonstrated improved performance with the incorporation of cellulose. The 35% cellulose concentration recorded the highest mean tensile strength (8.87 MPa), while the 0% cellulose obtained the lowest value (4.97 MPa), indicating that moderate cellulose addition enhances mechanical properties. In terms of water resistance, the 70% cellulose sample showed the lowest mean mass gain (2.73 g), suggesting better resistance to moisture absorption compared to the other treatments. For biodegradability, the 35% cellulose formulation exhibited the highest mean mass loss (0.33 g), reflecting faster degradation, whereas the 70% cellulose degraded the slowest. Statistical analysis revealed no significant difference in tensile strength and water resistance ($p > 0.05$), but a significant difference was observed in degradation ($p < 0.05$), implying that cellulose concentration significantly affects the biodegradation behavior of the developed bioplastic

3.2 Analysis of variance (ANOVA)

Table 4. One-Way ANOVA for Tensile Strength

Source of Variation	***SS***	***df***	***MS***	***F***	***p-value***
Between Groups	*23.17*	*2*	*11.585*	*3.33*	*> 0.05*
Within Groups	*20.87*	*6*	*3.478*		
Total	***44.04***	***8***			

The mechanical testing aimed to determine if adding cellulose increased the structural integrity of the bioplastic. While the 35% concentration reached a peak mean tensile strength, the statistical analysis suggests this increase was not definitive.

As shown in Table 1, the One-Way ANOVA for tensile strength resulted in an *F*-value of (3.33) and a p-value of (0.11). Since the *p*-value is greater than the significance level of (> 0.05), the researchers fail to reject the null hypothesis. This indicates that there is no statistically significant difference in tensile strength between the three groups, implying that under the current formulation, the amount of cellulose did not significantly change the material's resistance to breaking.

Table 5. One-Way ANOVA for Water Resistance

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*
Between Groups	*0.21*	*2*	*0.1*	*1.21*	*> 0.05*
Within Groups	*0.51*	*6*	*0.09*		
Total	***0.72***	***8***			

The results for water resistance showed that the F-value is 1.21 and the p-value is greater than 0.05. Since the *p*-value is greater than the significance level of (> 0.05), the researchers fail to reject the null hypothesis. The researchers did see some differences in how much mass was gained by each treatment but these differences in water resistance are not really significant, for the cellulose treatments. The water resistance of the cellulose treatments does not have any differences.

Table 6. One-Way ANOVA for Degradation

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*
Between Groups	*0.11*	*2*	*0.055*	*13.75*	*< 0.05*
Within Groups	*0.02*	*6*	*0.004*		
Total	***0.13***	***8***			

The results of the One-Way ANOVA showed a *F*-value of 13.75 with a p-value less than 0.05. Since the *p*-value is lower than the 0.05 level of significance, the null hypothesis is rejected. This indicates that there is a statistically significant difference in degradation among the cellulose concentrations. Therefore, cellulose content significantly influences the biodegradation behavior of the developed bioplastic.

IV. DISCUSSION

In this study, the effects of varying cellulose concentrations on the tensile strength, water resistance, and water degradation of alginate-based bioplastic films were evaluated. Statistical analysis was conducted to determine whether differences among treatments were significant at the 0.05 level of significance, and the findings were interpreted in relation to existing literature.

The results showed that varying cellulose concentrations did not produce a statistically significant difference in tensile strength, as indicated by a p-value greater than 0.05. Although the 35% cellulose formulation exhibited the highest mean tensile strength, the differences among treatments were not statistically significant, suggesting that cellulose content did not substantially enhance the mechanical strength of the bioplastic films. [18] Similar findings have been reported in previous studies where natural fiber incorporation into alginate matrices did not always result in significant tensile improvement due to limitations in fiber–matrix interaction.

The reinforcing efficiency of cellulose depends largely on strong interfacial adhesion and effective stress transfer between the fiber and polymer matrix. [25] Research has shown that insufficient bonding between reinforcing fibers and the surrounding polymer can significantly reduce mechanical enhancement even when fibers are uniformly dispersed. In the present study, weak interfacial compatibility between cellulose and alginate may have limited effective load transfer, thereby minimizing the expected strengthening effect. These findings suggest that cellulose incorporation alone may not significantly improve tensile properties without additional surface treatment or processing modification.

Similarly, varying cellulose concentrations did not produce a statistically significant difference in water resistance (mass gain), as indicated by the computed *F*-value of 1.21 and *p*-value of 0.36, which is greater than the 0.05 level of significance. Although the 35% cellulose formulation exhibited the highest mean mass gain and the 70% formulation showed the lowest, these differences were not statistically significant, indicating that cellulose content did not substantially influence the material's resistance to water absorption. [19] Comparable results have been observed in cellulose–glycerol bioplastics, where changes in cellulose concentration did not significantly alter moisture-related properties such as water uptake and barrier performance. [20] Furthermore, studies explain that cellulose incorporation alone does not necessarily enhance water resistance in bioplastic films because both cellulose and seaweed-based polymers contain hydroxyl groups that attract water molecules. Due to this hydrophilic nature, improvements in moisture resistance often require hydrophobic modification or crosslinking strategies rather than simply increasing cellulose content. Thus, both the present findings and supporting literature indicate that cellulose addition alone may not significantly change the water resistance of alginate-based bioplastics.

In contrast, cellulose concentration influenced the water degradation behavior of the bioplastic films. The treatment containing 35% cellulose demonstrated the highest mean mass loss (0.33 g), indicating a faster degradation rate, while the 70% formulation showed lower mass loss, suggesting slower degradation. These results indicate that cellulose concentration plays a role in controlling the degradation performance of the material.

Previous research has demonstrated that cellulose can affect degradation behavior due to its hydrophilic characteristics, which promote water penetration into the polymer matrix and accelerate hydrolytic breakdown. Moderate cellulose concentrations may increase matrix porosity and enhance water interaction, thereby accelerating degradation. [21] Similar findings were also reported in the studies conducted to explore the aqueous biodegradation of polysaccharide-based composites, where films containing alginate and cellulose nanocrystals showed considerable mass loss and degradation when exposed to water, suggesting that the nature of the component, being hydrophilic, plays an important role in the degradation process. [19] However, higher cellulose content may contribute to a denser internal structure that restricts water diffusion, resulting in slower degradation. Overall, the findings suggest that while cellulose incorporation may not significantly enhance tensile strength and water resistance, it can influence degradation rate, highlighting the importance of formulation balance and material compatibility in optimizing bioplastic performance.

V. CONCLUSION

1. Varying cellulose concentrations (0%, 35%, and 70%) did not significantly affect the tensile strength of the developed bioplastic ($p > 0.05$), indicating that mechanical strength is largely independent of cellulose content.
2. Water resistance of the bioplastic was not significantly influenced by cellulose concentration, suggesting that cellulose does not enhance this property.
3. Water Degradation was significantly affected by cellulose concentration ($p < 0.05$), as shown by differences in water degradation among samples.
4. The formulation containing 35% cellulose exhibited the highest mass loss and fastest degradation rate, indicating that this concentration optimizes biodegradability.
5. Overall, cellulose acts as a key determinant of bioplastic biodegradability while having minimal impact on mechanical strength and water resistance.

RECOMMENDATIONS

Following recommendations should be suggested:

1. The study recommends testing a wider range of cellulose concentrations to determine the optimal balance between tensile strength, water resistance, and water degradation.

2. The use of other additives, reinforcing materials, or alternative processing methods should be explored to further improve the quality and performance of the bioplastic.

3. The cellulose extraction process should be improved to ensure more consistent and higher-quality cellulose, which may enhance the properties of the bioplastic.

4. The number of trials and samples should be increased to obtain more reliable, accurate, and statistically valid results.

5. The bioplastic should be evaluated under real-life conditions, such as packaging applications, to gain better insights into its durability, usability, and practical performance.

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