

Improvement of the Mechanical Properties of Taro and Potato Starch-based Bioplastics with Abaca fiber (*Musa textilis*) and Peanut Shell (*Arachis hypogaea*) Filler

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Abstract— Plastic pollution remains a major environmental issue, emphasizing the urgent need for sustainable alternatives like bioplastics. This study sought to improve the mechanical properties of starch-based bioplastics by using organic fillers such as abaca fiber and peanut shell. Tensile strength, percentage elongation, water absorption, thickness, and biodegradability were all tested on three bioplastic formulations with different filler concentrations (10%, 20%, and 30%). The results revealed that Bioplastic 3 (30% filler) had superior mechanical qualities, with a tensile strength of 193.83 kPa, which was much higher than the bioplastic developed by Intong (2024) (160.71 kPa). Bioplastic 2 had the highest percentage elongation (9.48%), surpassing the original bioplastic's 6.38%. Biodegradability tests found that Bioplastic 3 had an 86.20% breakdown rate, indicating more environmental sustainability than Intong's (2024) bioplastic. Kruskal-Wallis and ANOVA tests revealed significant differences between formulations, especially in tensile strength and elongation ($p < 0.05$). These findings highlight the potential of abaca fiber and peanut shell in developing bioplastics, making them more durable and environmentally benign. Several changes are proposed to boost bioplastic production even more. First, experimenting with varied quantities of materials may result in more effective formulas. Using abaca fiber in its natural condition, rather than grinding it, may increase mechanical characteristics. Additionally, adjusting drying processes and durations may improve manufacturing efficiency. Further modification of filler ratios is recommended for improved performance. Scaling up usability tests will aid in the evaluation of real-world applications, whilst mold design changes may increase product quality and ease of manufacturing. These proposals are intended to increase the feasibility of bioplastics as sustainable plastic replacements.

Keywords— Bioplastics, Taro starch, Potato starch, Abaca fiber, Peanut shell, Natural fillers, Starch-based polymer, Sustainable materials, Eco-friendly packaging, Biodegradable plastic alternatives, Agricultural waste utilization.

I. INTRODUCTION

One of the most prevalent and urgent environmental problems of the twenty-first century are plastic pollution. The rapid proliferation of plastic items, driven by their affordability, longevity, and ease of use, has resulted in a significant accumulation of plastic waste in both marine and terrestrial ecosystems. Conventional plastics, derived from burning fossil fuels, pose long-term environmental hazards due to their

extreme durability, taking hundreds of years to decompose. As the world grapples with the severe consequences of plastic pollution, the demand for sustainable alternatives has intensified. One promising solution is the development of bioplastics, which are produced from renewable materials and offer the potential to mitigate the environmental impact associated with traditional plastics.

Bioplastics have been chosen as an alternative to plastic due to their ability to biodegrade in a short time, compared to the extremely long amount of time needed to biodegrade conventional plastic. The European Norm EN 13432 defines ultimate biodegradability as the “degradation mechanism characterized by the breakdown of organic chemicals by microorganisms in the presence of oxygen to carbon dioxide, water, mineral salts or other elements (mineralization), and biomass, or in the absence of oxygen to carbon dioxide, methane, mineral salts, and new biomass (Mastrolia et al., 2022).

When compared to traditional plastics, bioplastics may have a lower carbon footprint because they are made from natural resources including cellulose, sugarcane, and corn starch. Despite these advantages, the use of bioplastics has challenges also. The main issue is that bioplastics often possess worse mechanical properties compared to the petroleum-based. Because of their lower flexibility, tensile strength, and impact resistance, bioplastics are not as useful in applications where performance and durability are essential. Bioplastics might not yet reach the criteria needed for long-term usage, for instance, in the packaging, building, and automotive industries where materials are subjected to severe stress and wear.

Furthermore, one major disadvantage of bioplastics is their lack of durability. Although biodegradability is a good thing for the environment, it can also cause things made of bioplastics to break down more quickly. This decreased durability may cause early deterioration while in use, which would increase the amount of material used and waste produced. For bioplastics to be developed, achieving a balance between biodegradability and enough durability is still a major difficulty.

Although the performance and behavior of bio composites have been studied extensively, and many patented products have been fabricated, the use of bio composites for advanced applications still needs to be explored. This is due to their insufficient mechanical strength and lack of long-term performance studies reported on this new class of sustainable materials (Chang et al., 2020)

In order to improve the mechanical qualities and durability of bioplastics, there is an increasing demand for research and innovation in this area. The goal of this study is to continue the research of Intong (2024) to improve the bioplastics she produced into a product that is durable and with better properties using abaca fiber and peanut shells as organic filler.

II. METHODOLOGY

A. Collection of Materials

The materials were bought from various sources that sell peanuts and abaca fiber. The peanut shells were obtained from Magay, Zamboanga City while the abaca fiber was bought online. The weight of peanut shells ranges from 20% to 30% of the total weight of shelled peanuts (Mandala et al., 2023). Therefore, roughly around 1-3 kg of peanuts is needed to produce enough peanut shells for this research. The quantity of the materials used was tested based on different amount of abaca fiber to peanut shells to be added to the original mixture. The amounts to be tested are 10%, 20%, and 30% of the total mixture and the ratios of abaca fiber to peanut shells to be used are 50:50.

B. Preparation of Materials

Wash then dry the Abaca fiber and Peanut shells. Prepare the base bioplastic mixture, the ingredients that was used include distilled water, glycerol, vinegar, tomato seeds, potato and taro starch, peanut shells, and abaca fiber. The glycerol, potato starch, taro starch, tomato seeds, abaca fiber were bought online. Peanut shells and vinegar were bought at Magay, Zamboanga City. Table 1 presents the tabulated materials. The equipment used in the study include pan, container, whisk, lighter, silicone spatula, table spoons, food weighing scale, digital spring scale, molder, and digital caliper.

C. Proportions of Ingredients

The base bioplastic mixture contains the following proportions, 900 mL of distilled water, 75 mL of vinegar, 75 mL of glycerol, and 150 grams of combined starch from taro and potato peels, three different amount of abaca fiber and peanut shells amounting to 10%, 20%, and 30% of the total mixture were tested. The proportions of materials were tabulated in Table 1.

D. Production of Bioplastic

The amount of ingredients that were used for each sample were measured carefully using a food weighing scale for accurate measurements. After measuring the ingredients, it was combined in a pan and the cooking process begin. The ingredients were cooked until it reached a paste like texture and after that the paste like product was transferred into the

molder and oven-dried it at 105 degree Celsius for 1 hour another viable method is by drying it at room temperature for about a week (Intong, 2024). Each proportion of the mixture has its own mold, resulting in a total of three molds. The mold design and dimensions used is shown in Figure 1. This dimensions and design is needed in order to produce 30 samples of 5x5 cm size.

TABLE 1. Proportions of Materials

Materials	Bioplastic with 10% filler	Bioplastic with 20% filler	Bioplastic with 30% filler
Abaca Fiber	60 grams	120 grams	180 grams
Peanut Shell	60 grams	120 grams	180 grams
Potato Starch	75 grams	75 grams	75 grams
Taro Starch	75 grams	75 grams	75grams
Distilled Water	900 mL	900 mL	900 mL
Vinegar	75 mL	75 mL	75 mL
Glycerol	75 mL	75 mL	75 mL
Tomato Seed	300 seeds	300 seed	300 seeds
Food Coloring	Red	Blue	Yellow

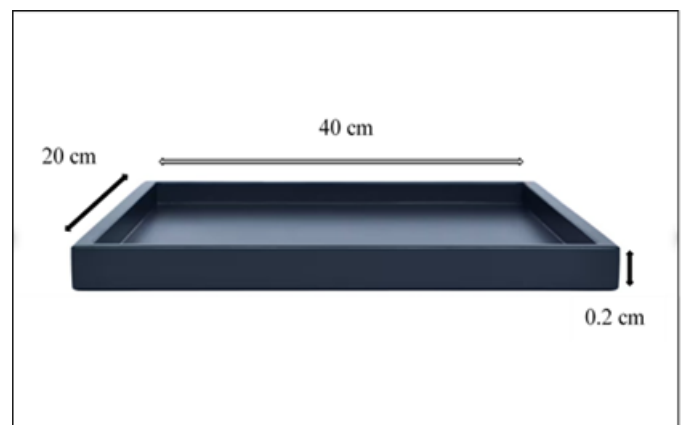


Figure 1. Design and Dimensions of Mold

E. Testing

In order to assess the quality and characteristics of the samples, five (5) tests with ten (10) trials were conducted on tensile strength, percentage elongation, water absorption, thickness, and biodegradability test. The test was conducted as soon as the sample of the product is done and test specimens were selected randomly to ensure unbiased representation. The bioplastic samples were cut equally into 5 x 5 cm size, the total samples produced was 30 for each proportion.

The samples were compared to the product of bioplastics using the same base mixture to assess whether the natural fibers and organic fillers used had an effect in terms of the mechanical properties of the samples.

Biodegradability Test

According to Madden (2020), the samples should be buried and retrieved after 12 weeks but since this study is time bounded the test was done for about a week only. The three proportions together with a control PPE plastic spoon were weighed initially and after the biodegrading process to evaluate the effectiveness of the sample's biodegradability. The samples were buried at least 8 cm deep in the ground and after the said duration, the samples were retrieved and all changes to the appearance of the samples were recorded. Ten

(10) trials were conducted and random sampling method was applied.

The degradation rate can be calculated by subtracting the final weight to the initial weight and be divided by the initial weight as shown in the formula below:

$$\text{Degradation Rate} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \times 100\% \tag{1}$$

Tensile Strength Test

The tensile test is carried out with the test object drawn from two directions so that the length increases and the diameter shrinks. The amount of load and length increase is recorded during the test. Tensile strength is the maximum load that can be accepted by the material (Sofiah et al., 2019). Ten (10) trials were conducted and random sampling method was applied.

The study used an improvised testing by using a clipper and digital spring scale, binder clips was used on both ends of the sample one to a stable hook then the other to the spring scale then the researcher pulled the sample until it breaks, the reading was then recorded and analyze using the formula below:

$$\text{Tensile Strength} = \frac{\text{Force}}{\text{Width} \times \text{Thickness}} \tag{2}$$

Percentage of Elongation

The elongation test of the bioplastic was conducted by measuring the initial and final gauge lengths after the rupture of four samples from the tensile strength test. In this process the researcher carefully and slowly pulled the spring scale until it reaches the point just before breaking in order to measure the final gauge length. The elongation was then calculated using the formula below:

$$\text{Percentage of Elongation} = \frac{\text{Final length} - \text{Initial Length}}{\text{Initial Length}} \times 100\% \tag{3}$$

Water Absorption Test

The samples were submerged in water at 23°C for 24 hours. Then after the immersion period the samples were removed, patted dry with a lint-free cloth, and weighed. The process was done to the three samples and the control PP. Ten (10) trials were conducted and random sampling method was applied.

Water absorption is expressed as an increase in weight percent or % weight gain of a plastic specimen and can be calculated using the formula below:

$$\text{Increase in Weight \%} = \frac{\text{Wet weight} - \text{Dry Weight}}{\text{Dry weight}} \times 100\% \tag{4}$$

Thickness and Percentage Shrinkage (in Thickness)

The thickness of the bioplastics was measured after the drying process using a digital caliper, and then the percentage shrinkage was calculated by measuring the original thickness after molding and the thickness after drying. The shrinkage

percentage is determined by calculating the ratio of the difference between the initial and final thickness to the initial thickness. The percentage shrinkage can be calculated using the formula below:

$$\text{Shrinkage in Thickness} = \frac{\text{Initial thickness} - \text{Final thickness}}{\text{Initial thickness}} \times 100\% \tag{5}$$

F. Interpretation of Data

Ten (10) trials were conducted for each parameter to ensure a high degree of accuracy in the results. The different properties of the bioplastics were compared to commercial plastics and to the product of Intong. The data were analyzed and interpreted based on the test results of the properties of the bioplastics, LDPE, and the original product. The normality test for the data was checked using Shapiro-wilk test and homogeneity test by Levene’s Test. If a significant level of more than 5% is achieved then ANOVA is utilized otherwise, non-parametric test like Kruskal Wallis Test is used.

III. RESULT AND DISCUSSION

Ordinal Ranking Method

TABLE 2. Bioplastics Overall Ranking

	Property					
	Water Absorption	Percentage Shrinkage	Tensile Strength	Percentage Elongation	Biodegradability	Total
Bioplastic 1 (10%)	3	5	1	1	2	11
Bioplastic 2 (20%)	1	4	3	4	3	13
Bioplastic 3 (30%)	4	3	2	2	5	16
Intong (2024)	2	4	4	3	4	14
LDPE	5	1	5	5	1	16

The relative performance of each filler ratio together with Intong and LDPE data was ranked from 5 to 1, where 5 denoted the best performance. While percentage shrinkage and water absorption were ordered in ascending order (lower is better), properties like tensile strength, biodegradability, and elongation were evaluated in descending order (higher is better). The sum of the ranks for every property was used to determine the overall rank for each filler ratio. The ideal filler ratio was defined as the one with the lowest total rank. Table shows the tabulated ranking of each sample.

Bioplastic 3 regularly outperformed other samples in terms of tensile strength and biodegradability, demonstrating the benefits of higher filler content. Bioplastic 1 had the least shrinkage, and Bioplastic 3 had the least water absorption. Overall, the 30% filler composition struck the optimal combination between strength, flexibility, and environmental performance, thus making it the ideal concentration.

Comparison between Bioplastics, Intong (2024), and LDPE

This bar chart compares the mechanical and biodegradable qualities of five materials: three bioplastics (Bioplastics 1, 2, and 3) Intong’s (2024) product, and LDPE. Water absorption, shrinkage, tensile strength, elongation, and biodegradability were among the important qualities evaluated.

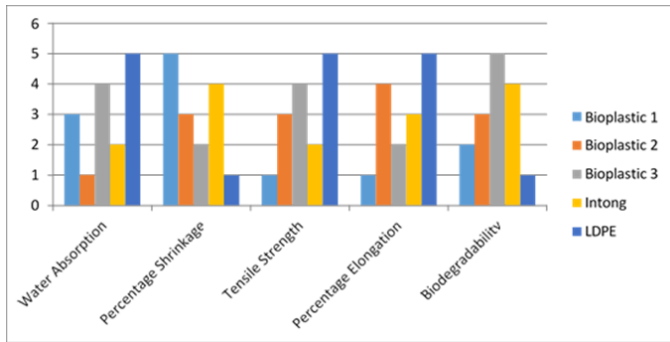


Figure 2. Chart Comparison of Bioplastics, Intong, and LDPE: Clustered Column

This comparison highlights the trade-offs between sustainability and mechanical performance in material selection. Bioplastics show promising biodegradability but vary in durability. The results suggest that tailoring bioplastic compositions can optimize mechanical strength for real-world applications.

IV. CONCLUSION

The conclusion of the study highlights that using abaca fiber and peanut shell as organic fillers significantly improved the mechanical and environmental properties of bioplastics. Specifically, Bioplastic 3 emerged as the most effective formulation, achieving the highest overall performance. It recorded the greatest tensile strength improvement, with a 20% increase compared to Intong's (2024) bioplastic, and exhibited the lowest water absorption rate at 14.77%, a notable advancement over the 27.43% of Bioplastic 1 and the previous standard. Bioplastic 3 also demonstrated an impressive biodegradability rate of 86.20%, far exceeding that of Intong's product, confirming the positive impact of higher filler concentration on environmental sustainability. While Bioplastic 1 had the lowest percentage shrinkage at 58.5%, Bioplastics 2 and 3 had higher shrinkage, likely due to their

higher filler content. In terms of flexibility, Bioplastic 2 achieved the highest percentage elongation at 9.48%, comparable to conventional LDPE, suggesting that filler ratios can influence different aspects of mechanical performance. Statistical analyses using ANOVA and Kruskal-Wallis tests at a 0.05 significance level validated that increased filler content (30%) enhances tensile strength and biodegradability, while lower ratios tend to reduce shrinkage and water absorption. These findings confirm that abaca fiber and peanut shell are effective natural reinforcement agents for developing stronger, more sustainable bioplastics.

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