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Taro *(Colocasia esculenta)* and sea grapes *(Caulerpa lentillifera)* as potential materials for making bioplastic

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Abstract

Plastic pollution has become a global concern, and the country Philippines is one of the plastic waste generators worldwide. The accumulation of non-recyclable, single-use plastics threatens marine life and contributes to global warming. This study aimed to contribute to reducing plastic pollution and provide insights into sustainable alternatives to single-use plastics. Hence, this research explores the potential of bioplastics as an alternative to traditional plastics. Specifically, this study primarily focused on developing bioplastics using taro and sea grapes as raw materials to provide an eco-friendly alternative to traditional plastics. The researcher aimed to investigate three different concentrations of bioplastic made from taro and sea grapes and evaluate their tensile strength, water absorbency, and biodegradability. The findings revealed that the second sample, consisting of 20 grams of taro starch, 15 mL of sea grape extract, two tablespoons of vinegar, 7.5 mL of glycerine, and 40 mL of water, exhibits the best outcome regarding its tensile strength, water absorbency, and biodegradability. Based on the results, the researchers concluded that bioplastics derived from taro starch and sea grape extract possess promising properties. The study highlights the importance of optimizing the concentration of raw materials to achieve desired characteristics in bioplastic production.

Keywords: Bioplastic, sea grapes extract, taro starch

INTRODUCTION

Over the years, the country Philippines has tremendously its human population [13]. In that case, the production and usage of plastics in the country also accelerate to suffice the need of individual consumers. The Philippines ranked third as the world's most significant plastic waste generator, with the second being Indonesia and China being the first [12]. According to the World Bank Organization's 2021 report, the Philippines generates an astounding 2.7 million tons of plastic waste annually, 20 percent of which ends up in the ocean, most of which consists of non-recyclable, single-use sachets [11]. Plastic is so pervasive that it has become an indispensable part of our daily lives**.** Almost every industry, including packaging, building and construction, textiles, consumer goods, transportation, electrical and electronic equipment, and industrial machinery, utilizes plastic in some capacity [3], [6], [20]. These plastics are primarily for single use, meaning they substantially increase the fraction of solid waste after using them once. Hence, more and more problems begin to arise. The vast majority of produced plastics are not biodegradable [6], [24]. A report by the World Wildlife Fund (WWF) reported that only 9% of plastic is recycled, and thus, the remaining 91% of plastic waste accumulates in land and water or even gets incinerated, causing harm to living things in them [3].

According to UNESCO (2022), 80% of marine pollution is made up of plastic garbage, and every year, 8 to 10 million metric tons of plastic enter the ocean [1]. When these plastics are thrown into bodies of water like rivers and oceans, they also become the source of additional aquatic issues. In addition, 17 percent of the species affected by the prevalence of plastic in the ocean are included on the International Union for Conservation of Nature's Red List of Threatened Species [4]. Furthermore, these plastics contain chemical compounds such as Polyethylene, Bisphenol, Polyvinyl Chloride, Polyethylene Terephthalate, and many more [23]. These chemical compounds can be converted to carbon dioxide (CO_2) through combustion, adding this gas to the atmosphere and causing global warming. The adverse effects of these plastics are readily apparent. The EPA (Environmental Protection Agency) estimates that almost all of the plastics ever produced by humans still exist. Thus, by 2050, research states that plastics will likely outweigh all fish in the sea. This indicates the exponential growth of plastics, and if the production and use of plastic continue, it may pose a more significant threat to the environment and all forms of life [14], [24]. Consequently, a course of action is required to mitigate its effects, and a wise alternative for this is bioplastic. The emergence of bioplastic innovation can be attributed to the growing concerns surrounding using single-use plastics. This is a relatively recent development in the field. Bioplastics are plastics derived from renewable biomass sources, including vegetable fats and oils, corn starch, straw, woodchips, and recycled food refuse [7]. Unlike traditional plastics, made by distilling and polymerizing nonrenewable petroleum reserves, bioplastics offer us ecological benefits that can help reduce the pollution of natural ecosystems and our energy footprint.

Bioplastics made from starch-based are more environmentally friendly and degrade faster than traditional plastics [5]. Starch extracted from Taro, a tuber growing in tropical due to its granule size, which falls between 1–5 mm (millimeter) [20]. The crystalline structure of Taro's starch would enable the starch to endure high heat and shear circumstances [15]. Seaweed and cellulose are promising natural polymers. Sea grapes (*Caulerpa lentillifera*) can be utilized in various ways, including as a food that is ingested directly or as an extract combined with other substances to create SARS Edible Straw [17]. Using sea grapes helps safeguard the environment by reducing the impact of plastic trash, which should now be managed and maintained in the best possible way [21]. In our school, Hilongos National Vocational School, inadequate waste disposal management has been identified as a problem. The data collected by the researchers indicates a widespread usage of disposable plastic materials within the premises of our school. The school has implemented a policy known as the "Zero Plastic Waste Project," intending to reduce plastic pollution within school premises. Nevertheless, this policy could have effectively addressed the issue of plastic waste management within our educational institution. As a result, the researchers aimed to address the environmental issues caused by plastic usage. The researchers aimed to develop a bioplastic utilizing Taro and Sea grapes as raw materials. The purpose of this study is to create a healthy environment and avoid plastic pollution.

MATERIALS AND METHOD

Research Design

This research utilized an experimental design. This study presented a potential alternative plastic that was concerned with and considered potential threats to biodiversity and the ecosystem. This research required an experimental data sheet to illustrate the procedure's efficacy further. The experiment lasted for two to three weeks due to the concern about the nature of the variables and their responses to treatments. Figure 1 shows the research diagram.

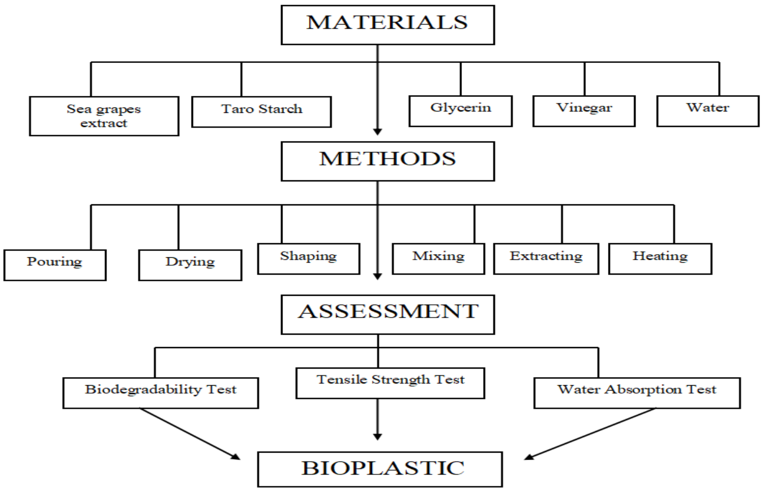

Figure 1. Research Diagram

Materials and General Procedure in Making Bioplastic

1. Starch was produced from the taro plant by grating the taro root and then squeezing it to get the extract. The extracted taro juice was placed in a flat container and dried within 1-2 days to get the taro starch.

Figure 2. Taro root

2. Sea grapes were dried up within 1-2 days. As it dried, it underwent a water bath to extract the sea grapes. A 120 mL of alcohol in every 10g of dried seagrapes was used in the water bath method.

Figure 3. Sea grapes

3. The other ingredients, including vinegar, glycerine, and water, were also prepared. The mentioned ingredients were combined according to their concentrations of taro and sea grapes.

Figure 4. Materials used in the experiment.

4. The different concentrations of taro starch, sea grapes extract, and other ingredients were mixed and heated until the desired consistency. The mixture was placed on a flat surface and dried within 1-2 days to form bioplastic.

Data Collection Process

1. Tensile Strength Test

The tensile strength test was used to determine the tensile strength of the bioplastic, which varied in different concentrations. First, a sample of every three (3) types of bioplastic was prepared. The sample was tied around the hook of the spring scale using a thread. Then, the force was applied until the sample failed, and the data was recorded.

2. Water Absorption Test

This test aimed to find out how well bioplastic could absorb water. In this test, the water absorption of bioplastic was measured in 50 mm x 50 mm. In the first step, a sample of bioplastic with dimensions of 50mm x 50mm was prepared from three different types of bioplastic. All the samples were weighed using a digital weighing scale. The data was recorded as an initial data point. The sample was immersed in three

(3) types of water (rainwater, tap water, seawater) at room temperature for forty-eight (48) hours. After forty-eight (48) hours, the samples were removed and wiped using tissue paper to remove the remaining water from the surface of the samples. Each sample was weighted, and data was recorded.

3. Biodegradability Test

The biodegradability behavior test was designed to determine the biodegradability of bioplastics using three (3) types of soil (Loam, Sand, Clay). This test was limited to fourteen (14) days to observe biodegradability behavior. In the beginning, samples of all three (3) types of bioplastic were prepared. All the samples were weighed using a digital weighing scale. The data was recorded as an initial data point. Next, the samples were buried for 14 days in different soils. With a seven-day (7-day) interval, the sample was removed from the soil. The samples were washed and dried. After, the sample was weighted, and the data was recorded.

Data Analysis

The study used a descriptive analysis method involving percentages and mean. In analyzing the tensile strength test, the researcher utilized Young's Modulus formula [26]. On the other hand, in analyzing the biodegradability and water absorption tests, the researcher also utilized a formula that calculates the percentage of weight loss in soil biodegradation [22] and water absorbency in the water absorption test [10]. Analysis of Variance (ANOVA) in the form of Complete randomized design (CRD) was employed to determine the significant difference between treatments. Additionally, Tukey honest significant difference (HSD) was also used for multiple comparisons of means and tested it at 1% and 5% levels of significance.

RESULTS AND DISCUSSION

This section presents the results and discussion of the three tests (tensile strength test, water absorption test, and biodegradability test) conducted in the three different concentrations of bioplastic. Table 1 shows the tensile strength of each different sample by concentration in unit MPa (Megapascal). The three types of concentrations were tested in three trials, and their total average per concentration was calculated in MPa. The first concentration was subjected to three trials, yielding pressure values of 0.003 MPa. The second concentration yielded pressure values of 0.005 MPa. The third concentration yielded pressure values of 0.006 MPa, in the first Trial and 0.007 MPa in both the second and third trials, with an average of 0.007 MPa. Using the ANOVA, it is shown that the different concentrations are statistically significant ($F=31.75$, $p\text{-value}<0.001$) to each other at a 1% level. By multiple comparison tests (Tukey HSD), it is depicted that the pairwise concentration differs significantly.

This result implies that concentration three (3) has the highest tensile strength with an average of 0.007 MPa, and concentration one (1) has the lowest tensile strength of 0.003 MPa. The tensile strength of each sample is directly proportional to the concentration of taro starch and sea grapes. This result contradicts Park et al. [19] study on "Tensile properties, morphology, and biodegradability of starch blends with various thermoplastics" They stated that lower starch concentrations give higher tensile strength values. This is due to the fact that their research is solely focused on starch-based bioplastics. However, the samples in this study were reinforced with sea grapes extract rich in cellulose. According to Genet et al. [9], cellulose has high tensile strength due to firm hydrogen bonds between the individual chains in cellulose microfibrils. Furthermore, cellulose-based biopolymers have garnered attention in recent years due to their strength, rigidity, high durability, and biodegradability. In conclusion, cellulose in sea grapes extract helped the concentration of bioplastic to get an equal ratio in tensile strength per concentration [2].

Table 1. Tensile Strength Test

Tensile Strength of Different Concentration (MPa)				
Concentration	**1st Trial**	**2nd Trial**	**3rd Trial**	**Average**
C1: 20g Taro starch & 5ml Sea grapes	0.003	0.002	0.003	0.003**c**
C2: 40g Taro starch & 15ml Sea grapes	0.005	0.005	0.005	0.005**b**
C3: 60g Taro starch & 25ml Sea grapes	0.006	0.007	0.008	0.007**a**

Note: Different assigned letter means statistically significant.

As shown in Table 2, the three types of bioplastic were immersed in different kinds of water (rainwater, seawater, and tap water) for forty-eight (48) hours. The first concentration accumulates 4% of absorbency in the three kinds of water (rainwater, salt water, and tap water), with an average of still 4%. The second concentration of bioplastic accumulates 6% of absorbency in rainwater and 9% in both salt water and tap water, with an average of 8% of absorbency in water. The third concentration accumulates 15% of absorbency in rainwater, 16% in salt water, and 11% in tap water, for an average of 14%. By ANOVA, the F-test (F=22.8, p-value=0.0016) showed that the different concentrations differ with respect to water absorption. In particular, the multiple comparison tests portrayed that concentration three has the highest water absorption percentage. The concentration with higher amounts of taro starch and sea grapes extract has a higher water absorption rate. The third concentration has the highest water absorption rate among the two concentrations.

Moreover, the first concentration has the lowest absorption rate. This implies that the water absorption rate varies directly with the concentration of the samples. Due to its inherent hydrophilic nature, starch is primarily responsible for the absorption of water by mixtures [18]. Furthermore, starch-based biodegradable plastics are water-sensitive, have high water vapor permeability, and generally provide films with mechanical properties unsuitable for many applications, which has hindered the expansion of their use and justifies the need to make modifications to improve their properties [15]. However, sea grape extract in the concentration makes the bioplastic improve its water resistance. In fact, in packaging applications, the majority of algae-based bioplastic films have high mechanical properties and a wide range of water vapor permeability [25].

Table 2. Water Absorption Test

Water Absorption (%) for 48 hours				
Concentration	**Rainwater**	**Seawater**	**Tap Water**	**Average**
C1: 20g Taro starch & 5ml Sea grapes	4%	4%	4%	4%**b**
C2: 40g Taro starch & 15ml Sea grapes	6%	9%	9%	8%**b**
C3: 60g Taro starch & 25ml Sea grapes	15%	16%	11%	14%**a**

Note: Different assigned letter means statistically significant.

Table 3 shows the biodegradability test using Loam. The ANOVA revealed that the three concentrations differ (F=31.40, p-value=0.0097) statistically at a 1% level. In particular, it is shown by Tukey HSD that the first concentration has the highest percentage of weight loss under the loam soil. This indicates that concentration 1, which has a lower concentration, degrades faster with 43% biodegradation compared to the two concentrations. However, the highest sample concentration biodegrades slowly, with a total percentage of 32%, 15% weight loss after seven (7) days, and 16% weight loss after fourteen (14) days. Biodegradation tests help determine the extent to which bioplastics can break down naturally in different environments, such as soil, compost, or aquatic systems. Assessing the biodegradability of bioplastics allows us to understand their potential impact on ecosystems and waste management practices [20], [25].

Table 3 Biodegradability Test (Loam)

Weight Loss (%) in Loam			
Concentration	**After 7 days**	**After 14 days**	**Total**
C1: 20g Taro starch & 5ml Sea grapes	22%	22%	43%**a**
C2: 40g Taro starch & 15ml Sea grapes	15%	17%	33%**b**
C3: 60g Taro starch & 25ml Sea grapes	15%	16%	32%**b**

Note: Different assigned letter means statistically significant.

Table 4 presents the soil biodegradation of the three samples in Clay for two (2) weeks. With the aid of ANOVA, it is revealed that the three concentrations do not differ (F=5.00, p-value=0.111) statistically from each other in terms of degradation under the clay soil. However, mathematically speaking, concentration 1, with a lower concentration, degrades faster than the other samples, with a total of 32% weight loss. The second and third samples have the same weight loss percentage of 27%.

Table 4 Biodegradability Test (Clay)

Weight Loss (%) in Clay			
Concentration	**After 7 days**	**After 14 days**	**Total**
C1: 20g Taro starch & 5ml Sea grapes	16%	17%	32%**a**
C2: 40g Taro starch & 15ml Sea grapes	14%	14%	27%**a**
C3: 60g Taro starch & 25ml Sea grapes	13%	15%	27%**a**

Note: Different assigned letter means statistically significant.

Table 5 presents the soil biodegradation of samples in Sand for two (2) weeks. Again, by ANOVA test, it is revealed that the three concentrations do not differ (F=1.77, p-value=0.31) statistically in regard to weight loss under the sand. However, numerically speaking, the highest weight loss in the sample is in the first concentration, with a percentage of 15% after 7 days, 17% after 14 days, and a total of 33% weight loss. Concentration 3 degrades slowly with a total of 25% weight loss.

Table 5 Biodegradability Test (Sand)

Weight Loss (%) in Sand			
Concentration	**After 7 days**	**After 14 days**	**Total**
C1: 20g Taro starch & 5ml Sea grapes	15%	17%	33%**a**
C2: 40g Taro starch & 15ml Sea grapes	12%	15%	27%**a**
C3: 60g Taro starch & 25ml Sea grapes	14%	11%	25%**a**

Note: Different assigned letter means statistically significant.

As shown in Figure 5, the result indicates that all concentration of samples of the bioplastic degrades faster in loam soil. Loam soil contains sufficient oxygen and water, as well as nutrients. Thus it is much easier for organic materials like bioplastic to degrade. Most microorganisms that facilitate biodegradation require light, water, and oxygen. According to Microbial Bioplastic Degradation, biodegradation of bioplastics can be carried out by microorganisms belonging to various taxonomic groups such as Firmicutes, Proteobacteria, Ascomycetes, and Basidiomycetes. Bioplastic samples in both clay soil and Sand have the same average weight loss percentage, but they differ in every concentration of the sample. The biodegradation process may be hindered by environmental factors present in the soil [8]. However, sandy soil exhibits high permeability, resulting in reduced nutrient content, contributing to slower bioplastic degradation compared to other soil setups. Additionally, clay soil makes the bioplastic degrade slower because of the high temperature at which it tends to experience dehydration and loss of water [22].

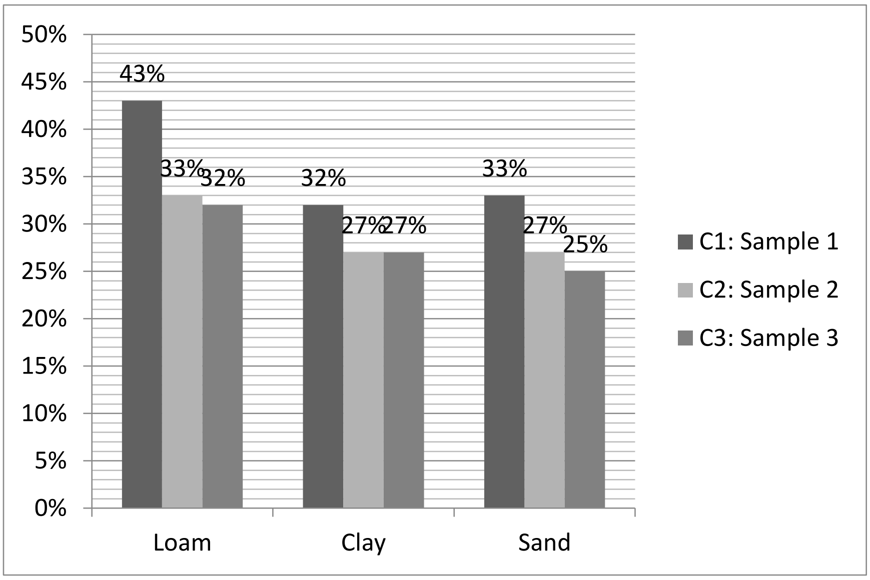

Figure 5. Weight loss percentage of samples in different soils.

Figure 6 presents the average percentage of weight loss for each sample, varying in concentration. Sample one, with the lowest concentration, attained the highest weight loss of 36% among the three. However, sample three, with the highest concentration, attained the lowest percentage of weight loss, which is 28%.

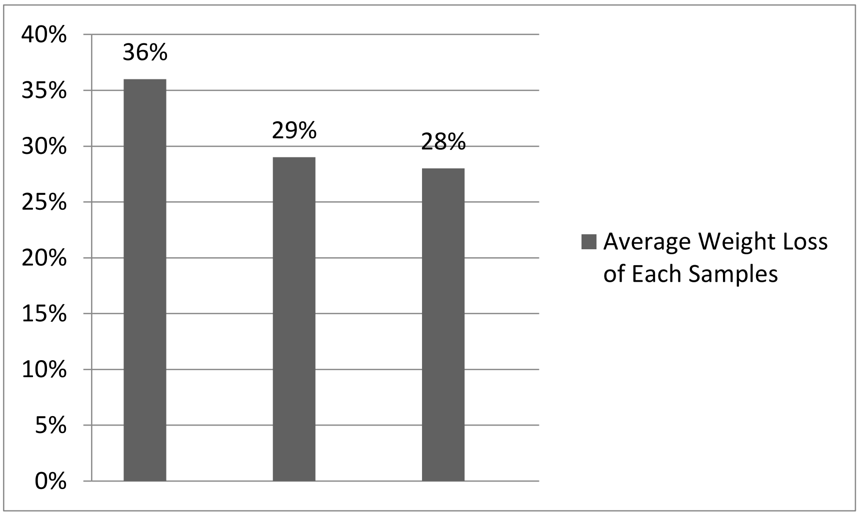

Figure 6. Average weight loss of each sample.

In that case, there is an inversely proportional relationship between each sample's concentration and the weight loss percentage. The increased concentration of taro starch and sea grape extract makes the bioplastic degrade slower. In [7], it is reported that starch bioplastics biodegraded entirely in 30 days, whereas the addition of cellulose to the formulation of bio-based plastics extended the biodegradation time. Thus, the concentration per sample plays a role in their biodegradability. As presented in Table 4, concentration, or sample one, is an effective bioplastic in terms of water absorbency and biodegradability, but it results in the lowest tensile strength among the three. Concentration three is the least effective in terms of water absorbency and biodegradability, but in terms of the tensile strength of the bioplastics, concentration three attained the highest value of tensile strength in MPa. Therefore, concentration two is the most considered effective bioplastic among the three regarding its tensile strength, water absorbency, and biodegradability.

Table 6. Differences in terms of tensile strength, water absorbency, and biodegradability

Differences in terms of tensile strength, water absorbency, and biodegradability			
Concentration	***Tensile Strength***	***Water Absorbency***	***Biodegradability***
C1: 20g Taro starch & 5ml Sea grapes	0.003 MPa	4%	36%
C2: 40g Taro starch & 15ml Sea grapes	0.005 MPa	8%	29%
C3: 60g Taro starch & 25ml Sea grapes	0.007 Mpa	14%	28%

CONCLUSION

The findings of the research suggest that an increase in the concentration of sea grape extract resulted in a corresponding increase in tensile strength. Conversely, an elevated level of starch concentration in bioplastic leads to increased water absorption, thereby resulting in an undesirable quality characterized by a higher percentage of water absorbency. Nonetheless, all concentrations of bioplastic degrade in different kinds of soil but vary in time and decay rate. Plastic pollution is becoming a concern on a global scale, posing challenges for human health as well as the marine and natural environments. The researcher highly suggests to legislators and lawmakers in the country that they impose laws, regulations, and policies that will mandate the use of bioplastic as an alternative plastic instead of traditional plastic. Prior to this suggestion, House Bill 9147 in the country Philippines passed its third reading. The bill requires the Department of Environment and Natural Resources (DENR) to develop a phase-out plan for single-use plastic waste within six months, with provisions for reducing consumption, increasing recovery, holding producers accountable, developing alternatives, and increasing public awareness. Thus, researchers recommend imposing this bill as an official law to resolve the problem of plastic waste. This study recommends utilizing renewable and highly abundant resources such as the taro plant and sea grapes in producing bioplastic that could serve as an alternative to petrochemical plastic, which is very harmful to all of us. The researchers recommend that future researchers widen their scope of bioplastics and suggests considering factors that can affect the samples in testing their mechanical properties, such as environmental factors. In addition, the researcher suggests increasing the amount of sea grape extract and decreasing the amount of taro starch to produce a much better outcome. Moreover, it suggests that future researchers must also consider the number of other ingredients in making bioplastic. The researchers suggest in trying other tests in assessing the quality of bioplastic generated from taro starch and sea grapes extract so that it can create a piece of reliable information for the future development of bioplastic.

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